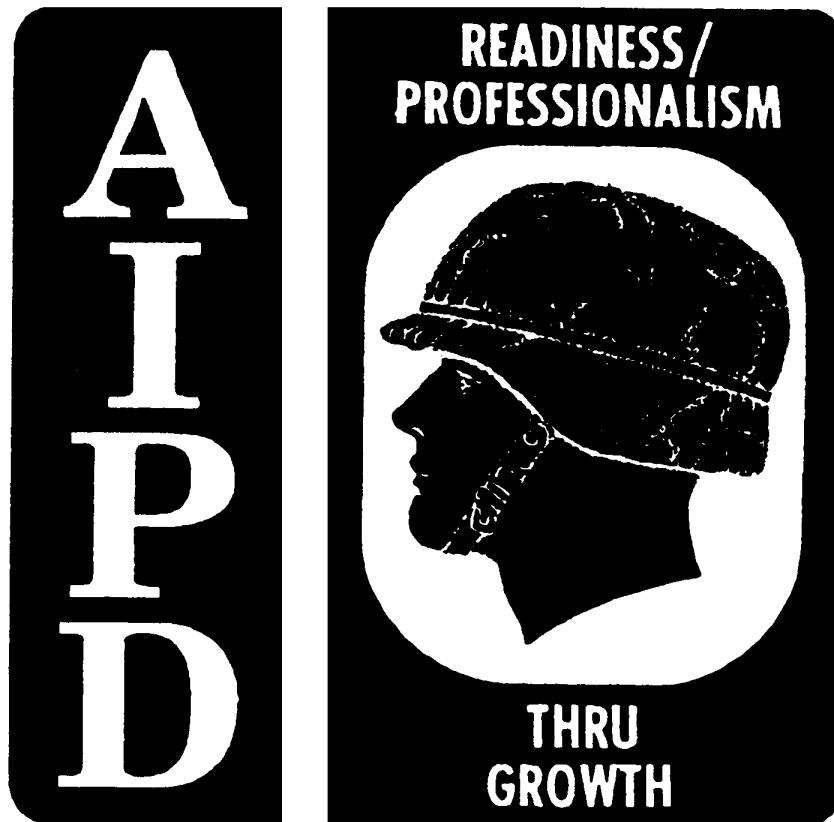

US ARMY ORDNANCE CENTER AND SCHOOL

**WHEELED VEHICLE FUEL
AND EXHAUST SYSTEM**



THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

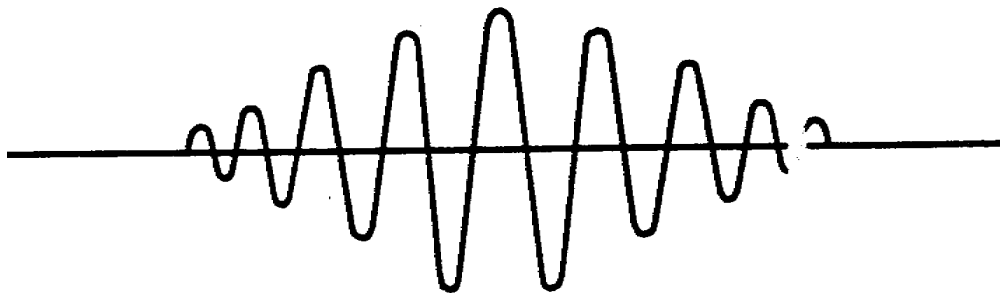
ARMY CORRESPONDENCE COURSE PROGRAM



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US ARMY LIGHT WHEEL VEHICLE MECHANIC
MOS 63B SKILL LEVEL 3 COURSE

WHEELED VEHICLE FUEL AND EXHAUST SYSTEMS

SUBCOURSE NO. OD1004
EDITION 6
US Army Ordnance Center and School

Five Credit Hours

GENERAL

The Wheeled Vehicle Fuel and Exhaust Systems subcourse, part of the Light Wheel Vehicle Mechanic MOS 63B Skill Level 3 Course, is designed to teach the knowledge necessary to develop the skills to service and maintain fuel and exhaust systems. This subcourse provides information about the fuel and exhaust systems for both spark ignition and compression ignition engines. It also provides information on inspection procedures for these systems. The subcourse is presented in three lessons. Each lesson corresponds to a terminal objective as indicated below.

Lesson 1: FUNDAMENTALS OF GASOLINE ENGINE FUEL SYSTEMS

TASK: Describe the fundamentals of gasoline engine fuel systems.

CONDITIONS: Given information about the types, location, operation, and inspection of gasoline engine fuel and air system components.

STANDARDS: Answer 70 percent of the multiple-choice items on the examination covering the fundamentals of gasoline engine fuel systems.

Lesson 2: FUNDAMENTALS OF COMPRESSION IGNITION ENGINE FUEL SYSTEMS

TASK: Describe the fundamentals of compression ignition engine fuel systems.

CONDITIONS: Given information about the types, location, operation, and inspection of compression ignition engine fuel system components.

STANDARDS: Answer 70 percent of the multiple-choice items on the examination covering the fundamentals of compression ignition engine fuel systems.

Lesson 3: ENGINE EXHAUST SYSTEMS

TASK: Describe the fundamentals of engine exhaust systems.

CONDITIONS: Given information about the location, purpose, construction, and inspection of engine exhaust systems.

STANDARDS: Answer 70 percent of the multiple-choice items on the examination covering the fundamentals of engine exhaust systems.

TABLE OF CONTENTS

Section	Page
TITLE PAGE.....	i
TABLE OF CONTENTS.....	iii
INTRODUCTION TO WHEELED VEHICLE FUEL AND EXHAUST SYSTEMS.....	vi
Lesson 1: FUNDAMENTALS OF GASOLINE ENGINE FUEL SYSTEMS	
Learning Event 1: Describe the Components of Gasoline Engine Fuel Systems.....	1
Learning Event 2: Describe the Principles and Operation of Carburetors.....	12
Learning Event 3: Describe the Procedures for Inspection of Gasoline Engine Fuel Systems.....	26
Practice Exercise.....	29
Answers to Practice Exercise.....	30
Lesson 2: FUNDAMENTALS OF COMPRESSION IGNITION ENGINE FUEL SYSTEMS	
Learning Event 1: Describe the Components, Principles, and Operation of Fuel Injection Systems.....	31
Learning Event 2: Describe the Principles and Operation of Compression Ignition Engine Air Induction Systems	43
Learning Event 3: Describe the Procedures for Inspection of Compression Ignition Engine Fuel Systems.....	49
Practice Exercise.....	56
Answers to Practice Exercise.....	58

Section	Page
Lesson 3: ENGINE EXHAUST SYSTEMS	
Learning Event: Describe the Components, Construction, and Inspection of Exhaust Systems.....	59
Practice Exercise.....	66
Answers to Practice Exercise.....	68

*** * * IMPORTANT NOTICE * * ***

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%
PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

INTRODUCTION TO WHEELED VEHICLE FUEL AND EXHAUST SYSTEMS

It is the job of the fuel system to send the correct fuel-air mixture to the engine at all times. The contents of the mixture and the amount of the mixture must be variable to meet the ever-changing needs of the engine. Through the years, it has taken a lot of research and experiments to develop the present-day fuel system. This system must be serviced and maintained properly or it will not work as it should.

The combustion (burning) of the fuel with the air in an engine includes several chemical changes. For example, for each gallon of gasoline that is burned, about one gallon of water is produced in the form of steam. Another thing that is formed is carbon monoxide, a colorless, odorless, deadly, poisonous gas.

The exhaust stroke rids the engine of most of these combustion products, and the exhaust system takes the exhaust fumes away from the engine, cuts down the noise, and gets rid of the gases so that none of the carbon monoxide reaches the people in the vehicle. For safety of personnel, proper maintenance of the exhaust system is a must.

The purpose of this subcourse is to give you the knowledge to develop the skills to service and maintain fuel and exhaust systems.

**LESSON 1
FUNDAMENTALS OF GASOLINE ENGINE FUEL SYSTEMS**

TASK

Describe the fundamentals of gasoline fuel systems.

CONDITIONS

Given information about the types, location, operation, and inspection of gasoline engine fuel and air system components.

STANDARDS

Answer 70 percent of the multiple-choice test items covering fundamentals of gasoline engine fuel systems.

REFERENCES

TM 9-8000

Learning Event 1:

DESCRIBE THE COMPONENTS OF GASOLINE ENGINE FUEL SYSTEMS

The primary job of the fuel system is to supply the correct fuel-and-air mixture to the engine cylinders. To do this job, the system must have components that will store the fuel, remove impurities, send the fuel to a fuel-and-air mixer, meter the mixture, and send it to the separate cylinders.

Some of the components of the fuel system require very precise adjustments, and all of them require maintenance and care. It is therefore necessary for you, as a wheeled vehicle mechanic, to understand how each of the fuel system components works.

Although the locations of components on a wheeled vehicle may vary, each fuel system contains the same components.

FUEL TANKS

Fuel is stored in the fuel tank. The location of the tank is not important. Heavy trucks may have fuel tanks mounted in front of the rear wheels, and some tanks will be located under the driver's seat.

Lesson 1/learning Event 1

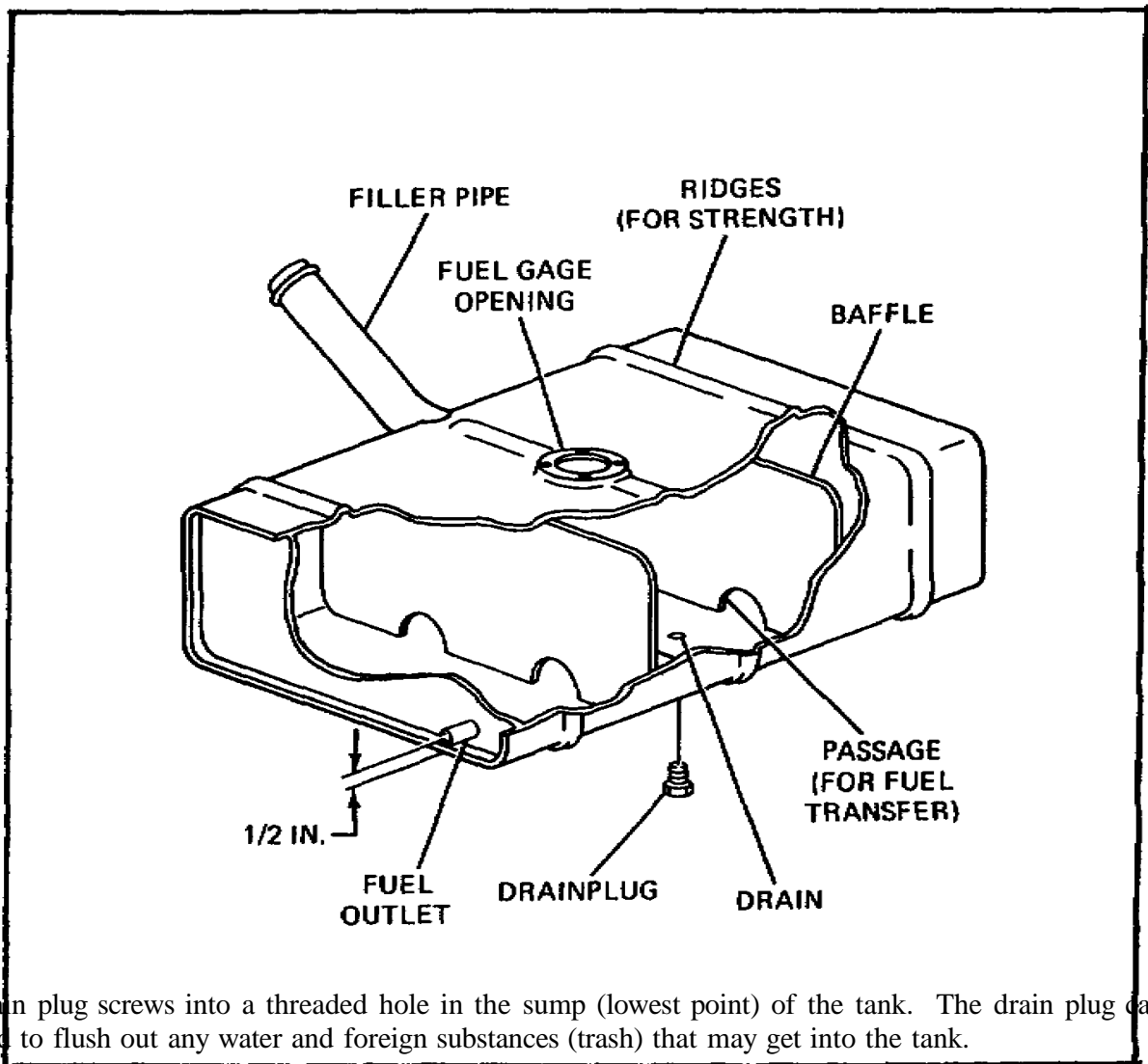
Most fuel tanks are made of thin steel sheet or plastic. The seams of the steel sheets are crimped or welded to make the tank leakproof, and the tank is coated inside and out to prevent rust. The coating used is called terneplate, an alloy of tin and lead.

Components of a Typical Fuel Tank

A funnel-shaped screen fits inside the filler neck on military vehicles to filter (strain) the gasoline before it enters the tank. (Screens are not used in the fuel tanks of civilian vehicles.) The screen is easily removed for cleaning.

On military vehicles, the fuel tank cap seals the filler neck when properly tightened. Military vehicles must be able to ford bodies of water, so the filler neck and all other openings in the tank must be watertight.

FIGURE 1. TYPICAL REMOVAL FUEL TANK CONSTRUCTION.



The drain plug screws into a threaded hole in the sump (lowest point) of the tank. The drain plug can be removed to flush out any water and foreign substances (trash) that may get into the tank.

Some tanks have baffle plates. Baffle plates strengthen the tank and reduce the sloshing of the fuel. On rough roads, fuel sloshing in the tank creates problems. First, fuel evaporates rapidly if it sloshes around in a container, especially in hot weather. Also, the sloshing fuel generates static electricity, and a spark in the fuel tank could cause an explosion. Baffles control the liquid and still allow the fuel to move freely through perforations.

An outlet pipe, also called the pickup tube, is installed through the top or the side of the fuel tank. The bottom tip of the pipe is positioned about half an inch above the bottom of the tank; this reduces the chances of picking up water or trash. (Sometimes the tip end of the pipe is shielded by a screen or filter to keep trash from entering.)

A vent tube is necessary so that outside air can fill up space left by the fuel drawn from the tank. The vent also allows air in the tank to escape when the fuel in the tank expands. (Fuel will always expand when the vehicle is standing in the hot sun.) On most military vehicles, the vent is a leakproof tube that connects the tank to the carburetor air cleaner. Sometimes the fuel pickup and vent tubes are placed close together. (The vent tube is smaller than the fuel pickup tube.)

A fuel gage sending unit is connected by an electrical wire to the fuel gage on the vehicle instrument panel. This sending unit shows the level of fuel in the tank.

MAIN FUEL LINE

Fuel from the tank is delivered to the engine by the main fuel line. This line is usually made of copper or steel tubing and is secured to the frame by clamps or clips to reduce the chances of breakage. At the engine compartment, a flexible hose connects the main fuel line with the filter or the fuel pump. Without this flexible hose, the main fuel line would be broken by vibration between the engine and the frame.

FUEL FILTERS

Filters are used to remove trash that could hurt engine performance or clog fuel passages.

The carburetor contains many small passages that can be easily clogged by trash. For this reason, fuel filters are located between the fuel tank outlet pipe and the carburetor. Some vehicles have more than one filter.

Lesson 1/Learning Event 1

Filters with a metal screen and a sediment bowl are in common use, but nowadays filters are often made of pleated paper and are disposable.

FUEL PUMPS

The fuel pump draws fuel from the tank and delivers it to the carburetor. The pump must deliver the right amount of fuel for engine operation for both light and heavy loads. In addition, it pressurizes fuel in the line between the carburetor and the pump. Pressure in the line reduces the possibility of the fuel vaporizing (boiling) because of heat from the engine.

Fuel pumps are generally classified either as positive or nonpositive.

- Positive-type pumps pump fuel continuously while the engine is running and must have some means of returning fuel that the engine does not use. Vehicles with positive fuel pumps pass excess fuel back to the fuel tank or to the inlet side of the fuel pump.
- Nonpositive-type pumps supply fuel only when it is needed.

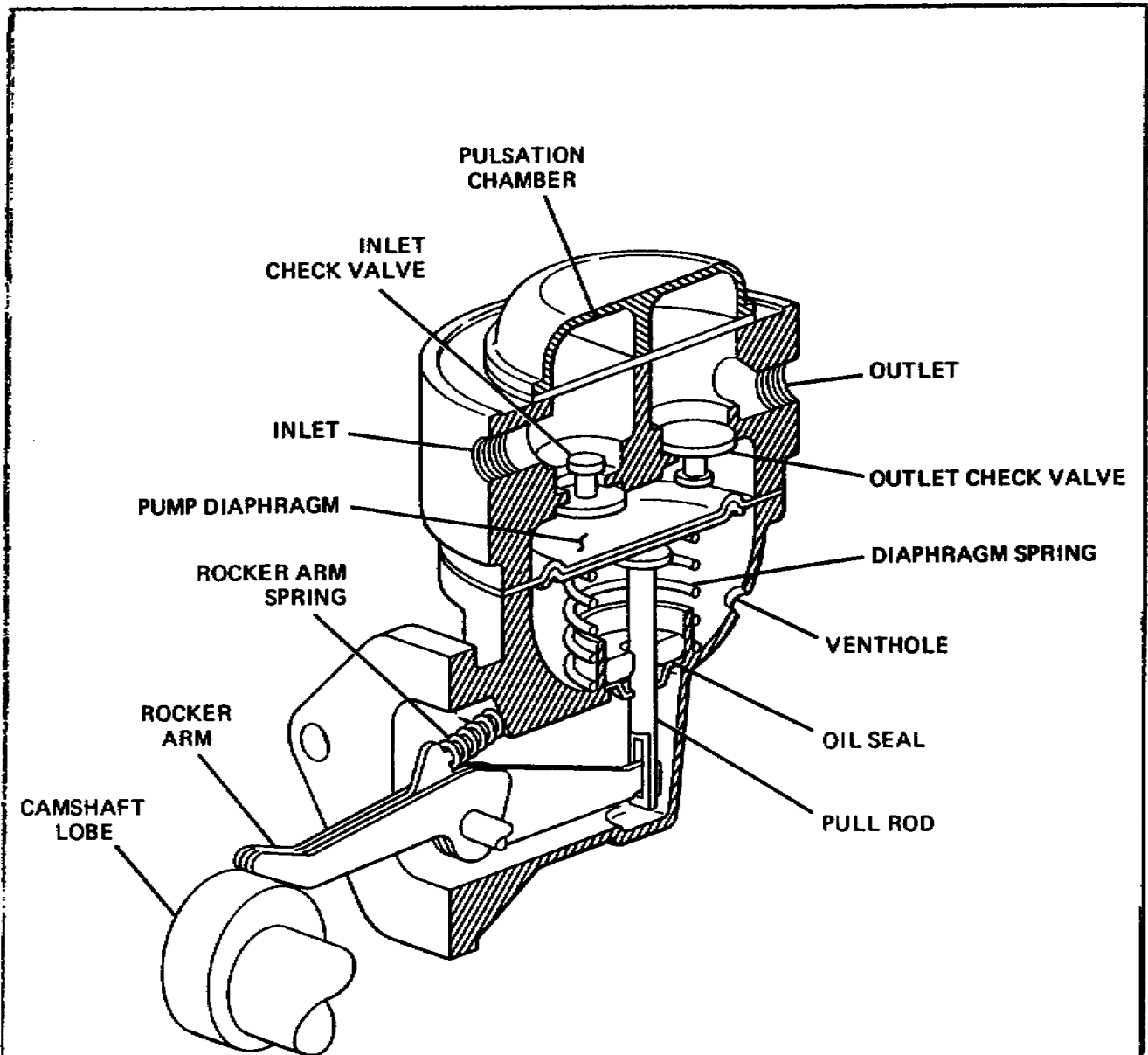
The fuel pump most widely used on wheeled vehicle gasoline engines is the nonpositive, diaphragm type. This type of pump is usually operated mechanically by the engine.

Diaphragm-Type Fuel Pumps

The operating linkage of the pump consists of a rocker arm, a link, and a spring. A flexible diaphragm is hooked to the link by a rod. The diaphragm is clamped at its outer edges by the two halves of the pump body. The pumping chamber is the area between the diaphragm and valve assemblies.

The fuel pump is mounted on the engine with its rocker arm in contact with an eccentric on the engine camshaft. As the eccentric turns, it forces the rocker arm and link to pivot (turn) on its pin and pull the diaphragm down. The downward movement of the diaphragm compresses the diaphragm spring and enlarges the pumping chamber. This creates a low-pressure area or vacuum (suction) in the pumping chamber. In the meantime, air entering the fuel tank vent at atmospheric pressure is pressing downward on the fuel in the tank. This pressure forces the fuel to flow from the tank, through the line, through the pump inlet valve, and into the low-pressure area of the pumping chamber. Remember that liquids or gases will always flow from a high-pressure area to a low-pressure area.

FIGURE 2. DIAPHRAGM-TYPE FUEL PUMP.



When the camshaft eccentric rotates 180°, it no longer pushes the rocker arm down. The rocker arm spring then forces the rocker arm to pivot on its pin in the opposite direction. The compressed diaphragm spring now pushes upward, putting pressure on the fuel in the pumping chamber. The pressure created by the diaphragm spring closes the inlet valve and forces fuel through the outlet valve to the carburetor bowl. The diaphragm moves up and down in this manner until the carburetor bowl is filled with fuel.

Lesson 1/learning Event 1

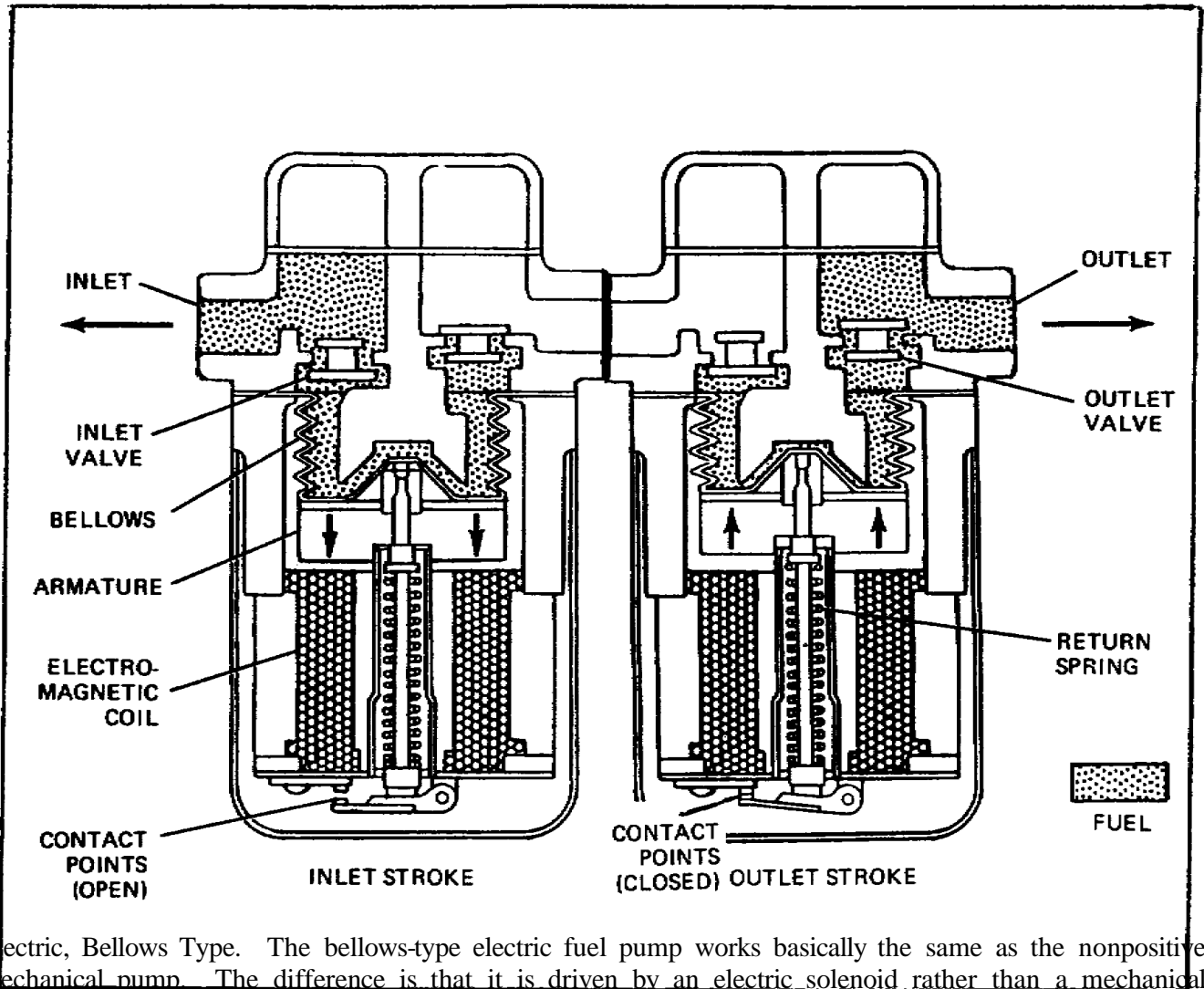
When the carburetor bowl is filled, a needle valve blocks the flow of fuel. This causes back pressure in the fuel discharge line and in the pumping chamber of the fuel pump. The diaphragm now has full back pressure on top of it and diaphragm spring pressure below. When the fuel pressure is the same as that of the compressed spring, the diaphragm will stop in its intake position (down). At this time, the rocker arm still pivots up and down, following the camshaft eccentric. However, the rocker arm will no longer move the link, because they are two separate pieces. (The rocker arm can move the link down, but it can never push it back up.)

When the carburetor needs more fuel, the needle valve of the carburetor opens, and the back pressure in the discharge line is relieved. This allows the diaphragm spring to push the diaphragm up, forcing more fuel into the carburetor past the opened needle valve. As the eccentric on the cam rotates, it causes the diaphragm to be pulled down again and pumping is resumed.

Electric Fuel Pumps

There are two types of electric fuel pumps used in military wheeled vehicles. These pumps are operated by either an electric motor or a solenoid.

FIGURE 3. BELLOWS-TYPE ELECTRIC FUEL PUMP.

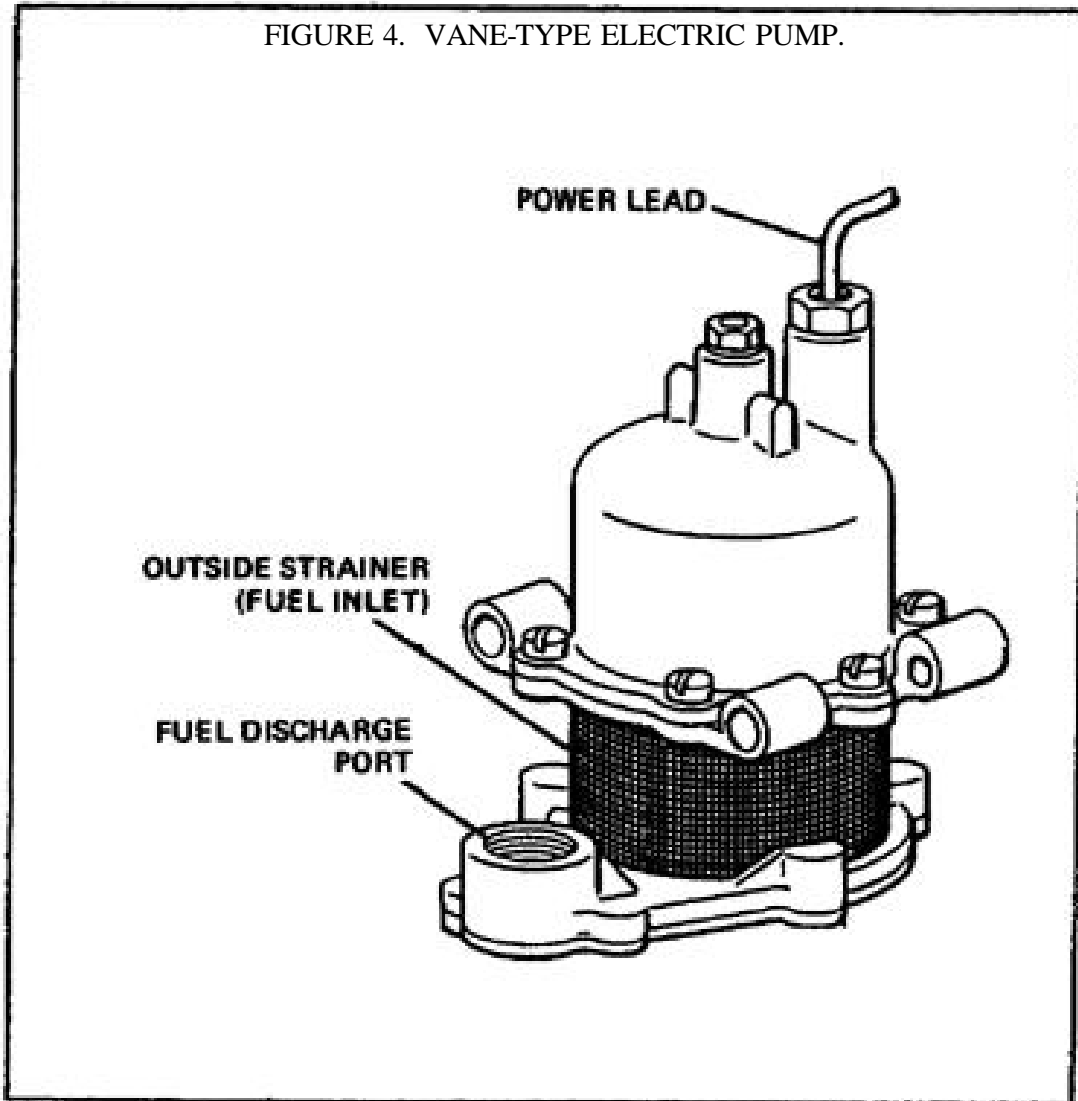


Electric, Bellows Type. The bellows-type electric fuel pump works basically the same as the nonpositive mechanical pump. The difference is that it is driven by an electric solenoid rather than a mechanical camshaft. Operation is as follows:

- As electric current is fed to the pump, the electromagnetic coil pulls the armature down, expanding the bellows.
- The expansion of the bellows causes fuel to be drawn in through the inlet valve.
- As the bellows fully expand, a pair of contact points opens, switching off the electromagnet.
- The return spring pushes the armature back up, contracting the bellows. This action pushes fuel out of the pump through the outlet valve.

Lesson 1/learning Event 1

- The contact points close as the bellows fully contract. This causes the electromagnet to pull the armature down and repeat the pumping process.
- The pump will stop when the fuel pressure is high enough to hold the bellows expanded against the return spring. The operating pressure of the pump is determined by the return spring pressure.



Vane Type. An integral steel rotor and shaft, one end supported in the pump flange and the other end in the cover, revolves in the body. The bore of the body is eccentric to the rotor. Two sliding vanes, 180° apart in slots in the rotor, are pressed against the body bore by springs in the slots. When the shaft is rotated, the vanes pick up fuel at the inlet port and carry it around the body to the outlet side, where the fuel is discharged. Pressure is produced by the wedging action of the fuel as it is forced toward the outlet port by the vane.

AIR FILTERS

A mixture of fuel and air is burned inside the engine cylinder during the power stroke. Mixing the fuel and air is one of the functions of the carburetor.

The air cleaner on an internal combustion engine serves three purposes:

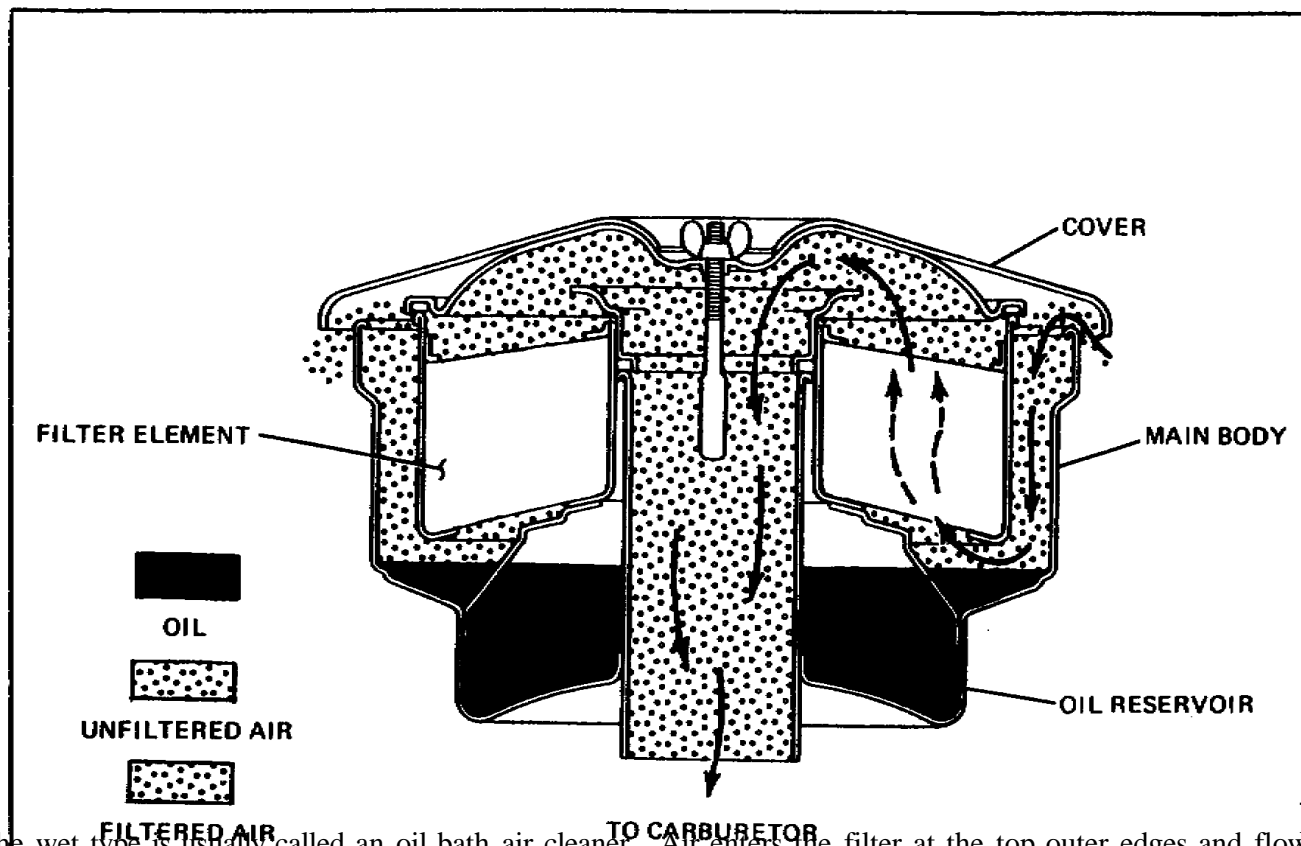
(1) It filters the air to remove dust and dirt before the air enters the carburetor. This is very important because the engine requires about 9,000 gallons of clean air for every gallon of fuel it burns.

(2) It acts as a flame arrester to prevent fires in case the engine backfires.

(3) It acts as a muffler, reducing the hissing noises made by the air entering the carburetor at high speed.

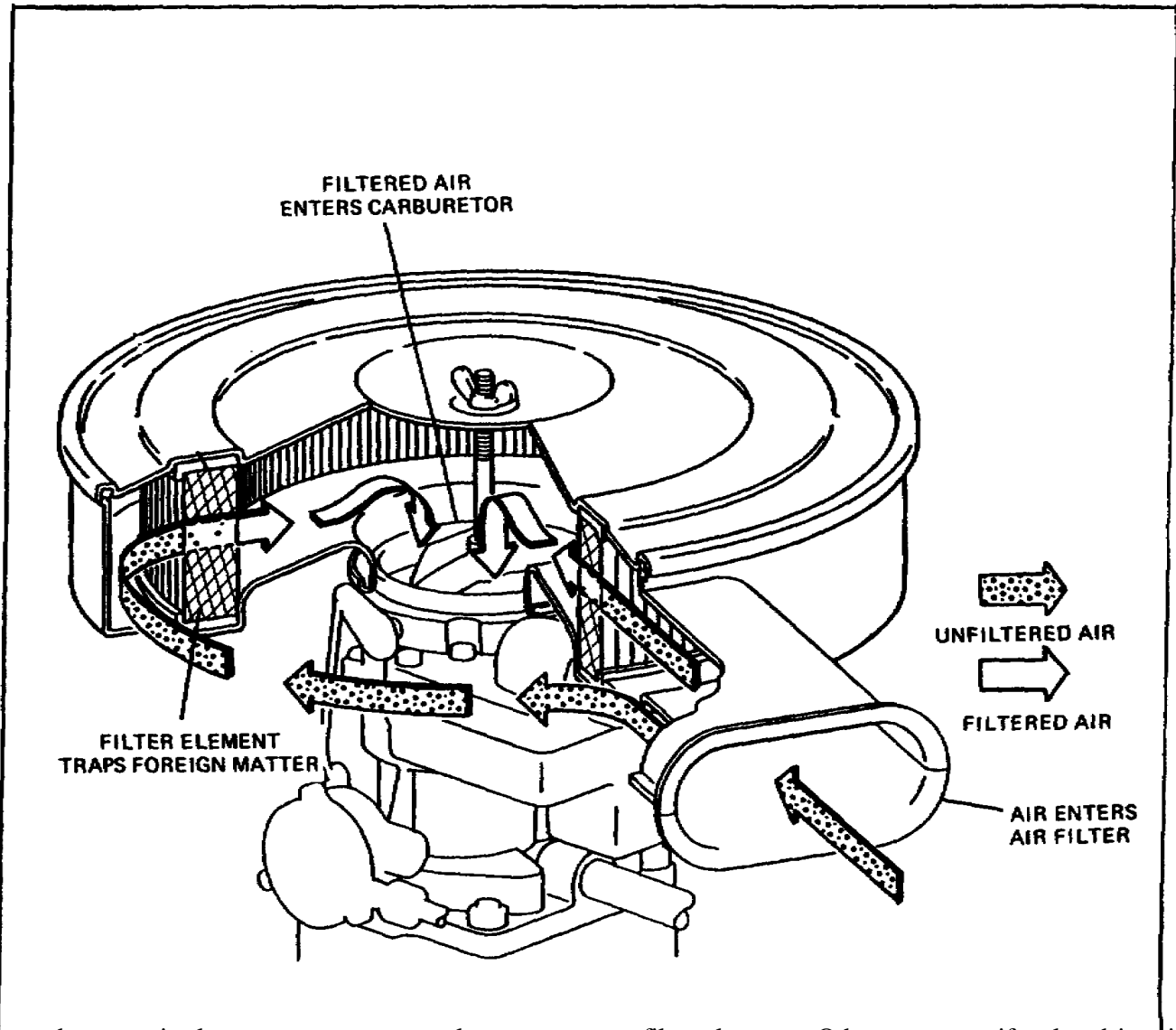
Air cleaners are generally classified as either wet or dry, depending on what method is used to filter the air.

FIGURE 5. WET-TYPE AIR FILTER.



The wet type is usually called an oil bath air cleaner. Air enters the filter at the top outer edges and flows around the sides over a bath of oil. The airflow then reverses direction and moves up through the filter element and to the carburetor. Heavier dust particles are separated from the air as the air passes the oil bath. As the air suddenly changes its direction of movement from down to up, the heavier dust particles continue to move down and are trapped in the oil. Lighter particles are trapped in the metal-gauze filter element. As the airflow reverses its direction above the oil reservoir, it picks up an oil mist from the oil bath to keep the filter element soaked.

FIGURE 6. DRY-TYPE AIR CLEANER.



Some dry type air cleaners may use a metal gauze or paper filter element. Others use centrifugal and inertial principles: Swirling motions and sudden changes in the direction of airflow separate the dust from the air.

Most dry filters in use today have a replaceable paper element. Air first enters an outer chamber around the filter element and is then filtered through small holes in the element before entering the carburetor.

Lesson 1/learning Event 2

Learning Event 2:

DESCRIBE THE PRINCIPLES AND OPERATION OF CARBURETORS

VAPORIZATION

Liquid fuel is sent from the fuel tank to the carburetor. To burn properly, the gasoline must be thoroughly mixed with air. To do this, the gasoline must be vaporized.

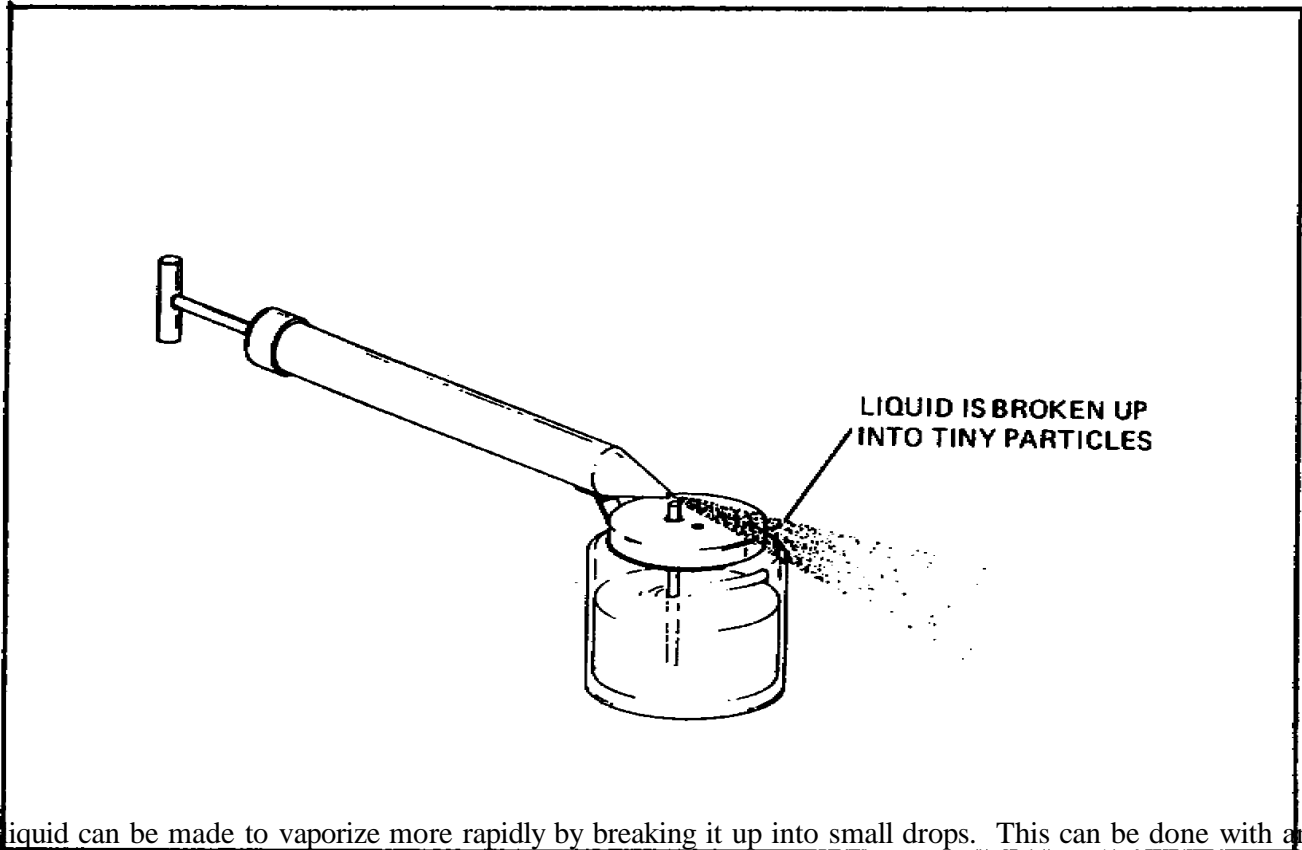
When any liquid changes to a vapor, it evaporates in the air. Boiling water is an example of vaporization. As the water boils, it steams. Steam is made up of liquid in very small particles. These tiny particles (vapor) mix with the surrounding air.

Several things determine how easily a liquid will vaporize. The nature of the liquid itself is one factor. For instance, it is a well-known fact that alcohol, which is lighter than water, vaporizes more easily than water. Gasoline, which is also lighter than water, vaporizes more easily than water.

A second factor controlling vaporization is the temperature. Higher temperatures cause liquids to vaporize faster. An example of this is water turning to steam when it is boiled.

Another factor controlling vaporization is the amount of vaporized liquid already in the air (humidity). You can understand this by thinking of the air as a sponge. When a dry sponge is placed in a pan of water, it soaks up (absorbs) a large amount of water very rapidly. But as the sponge begins to get full, it absorbs water more slowly. Finally, it reaches a point where it will not absorb any more water at all. Air acts in the same manner. When you hear the weatherman say that the humidity is 100 percent, this means the air has soaked up all the moisture it can hold at that temperature.

FIGURE 7. EXAMPLE OF ATOMIZATION.



A liquid can be made to vaporize more rapidly by breaking it up into small drops. This can be done with an ordinary spray gun. Breaking up a liquid into small droplets is called "atomizing" the liquid. When a liquid is atomized and air surrounds all the small drops, more of the liquid is able to come in contact with air at one time and the liquid will vaporize faster.

Gasoline that is not vaporized does not burn. Only the vapors burn. All the fuel in an engine's cylinder should be burned before the end of its power stroke. Fuel that is still in liquid form is wasted. The fuel that is left in the combustion chamber will be discharged through the engine's exhaust system. Some of it may go past the piston into the crankcase and mix with the oil. This can cause damage to the engine bearings because the gasoline will dilute the oil.

Gasoline fuels are blended mixtures that are refined from crude oil. Part of the mixture vaporizes at low temperatures for cold engine starts. Other parts of the mixture vaporize better as the engine warms up.

Lesson 1/learning Event 2

Highly volatile (easily vaporized) gasoline will burn too quickly, so the fuel-burning rate is slowed down by another substance that is part of the fuel mixture (usually tetraethyl lead). When fuel burns too rapidly, its energy or power is released very suddenly. This is like striking the top of the piston with a hammer. Vibrations caused by fuel burning too fast cause engine ping (sharp hammering noise in the engine). Engine ping, if allowed to continue, will damage engine parts.

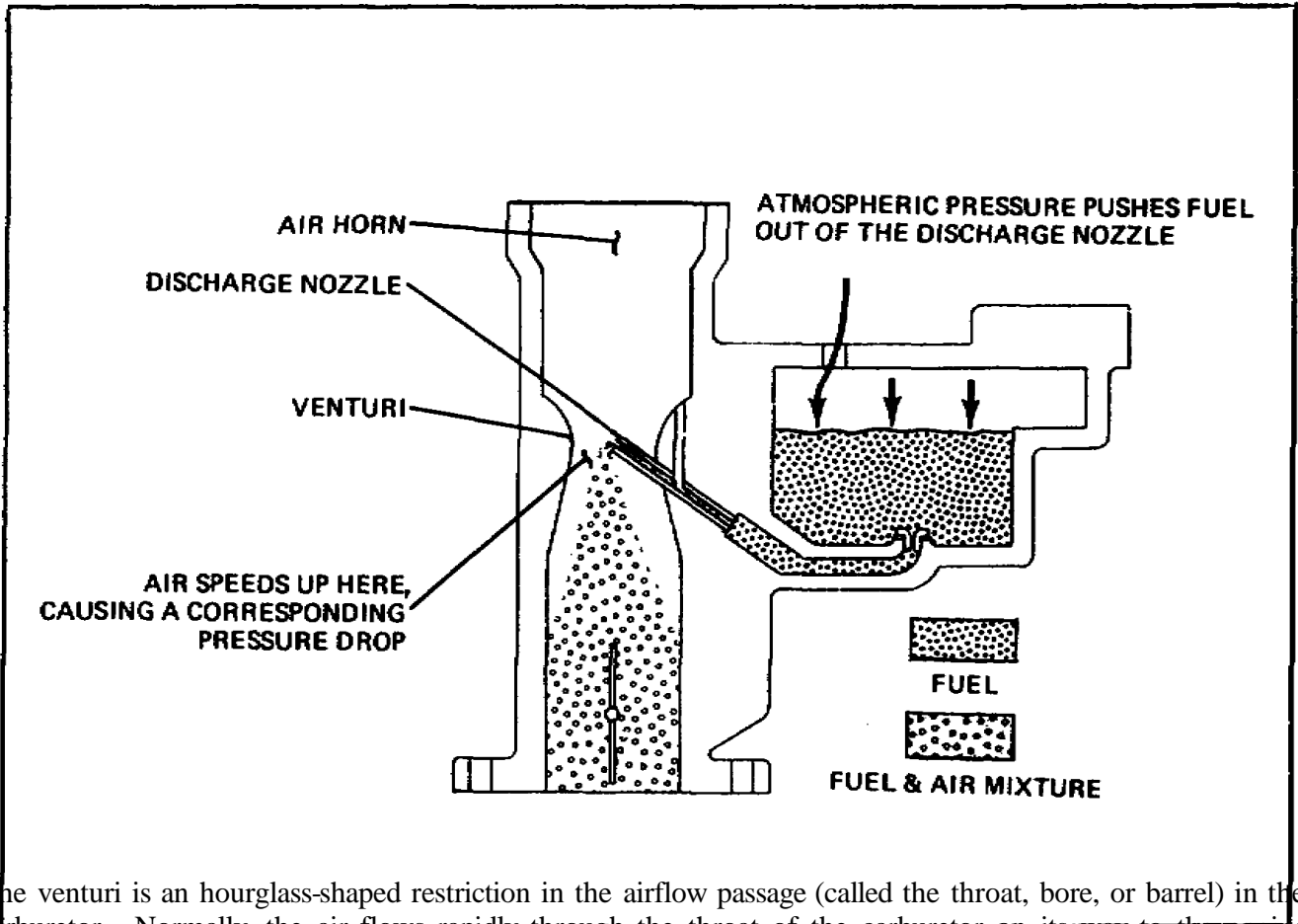
Octane numbers are assigned to different grades of gasoline. These numbers tell how fast the gasoline will burn. The octane rating of a gasoline blend (mixture) is determined by laboratory methods. Slower-burning blends have higher ratings. For example, a fuel with an octane rating of 80 will burn more slowly than one with an octane rating of 70.

Vaporization of the fuel in a gasoline engine starts in the carburetor. It continues as the fuel passes through the intake manifold and even after it enters the cylinder.

PRINCIPLES OF VENTURI ACTION

The main job of any carburetor is to supply the right mixture of air and fuel for any and all engine speeds and load conditions. To understand how the carburetor does this job, it is necessary to understand the principle of a venturi.

FIGURE 8. VENTURI EFFECT.



The venturi is an hourglass-shaped restriction in the airflow passage (called the throat, bore, or barrel) in the carburetor. Normally, the air flows rapidly through the throat of the carburetor on its way to the engine cylinders. When the fast-moving air reaches the venturi, it must speed up to get through the restriction.

When the air speed increases in the venturi, however, there is a drop in the air pressure. The faster the air moves, the more the pressure drops.

This principle also applies to the nozzle on a water hose. The nozzle itself is a restriction. The water speed increases as it leaves the hose and passes through the nozzle. That is why a stream of water leaving the nozzle travels much farther through the air than it does when there is no nozzle on the hose.

The important thing to remember about a venturi is that for any increase in the speed of the flow, there is a decrease in pressure. The pressure on the air entering the air horn (mouth) of the carburetor is about 14.7 pounds per square inch (PSI). This is normal atmospheric (air) pressure at sea level.

Lesson 1/learning Event 2

CARBURETOR COMPONENTS

In a simple carburetor, the gasoline is stored in the float bowl. A passage in the bottom of the float bowl leads to a discharge nozzle that is located in the center of the venturi.

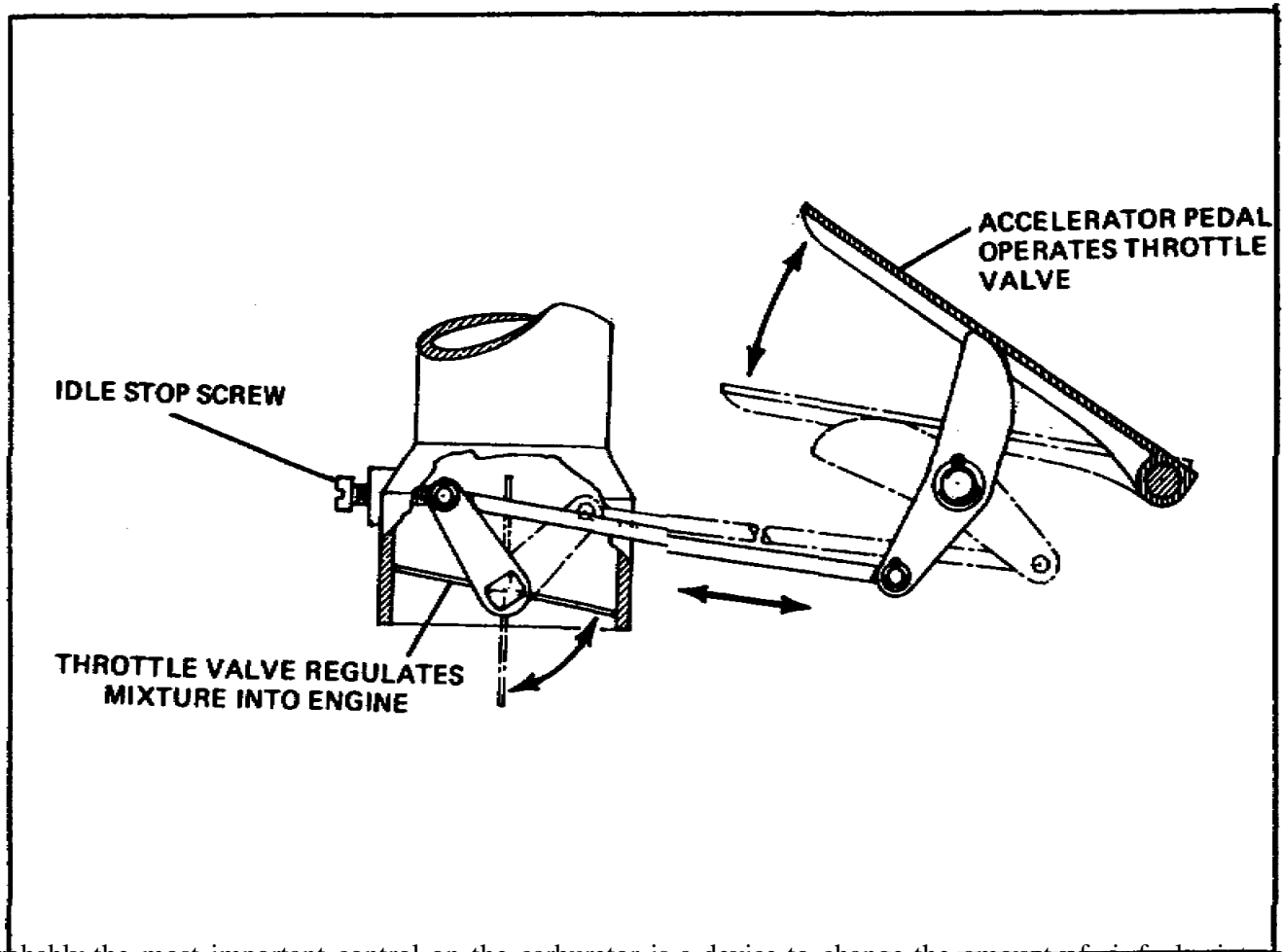
When the engine is running, each piston acts like an air pump during its intake stroke. A low-pressure area (vacuum) is created in the engine cylinder, and outside air rushes through the carburetor bore to fill the low-pressure area above the piston.

Air at atmospheric pressure is pushing down on the fuel in the float bowl. The discharge nozzle in the venturi is placed above the level of the fuel in the bowl. When the air rushing through the venturi creates a low-pressure area at the tip of the fuel nozzle, the atmospheric pressure on the fuel in the bowl will push fuel out through the tip of the nozzle. Gasoline leaving the nozzle and entering the airstream is broken into small droplets (atomized) by the fast-moving air.

The amount of air that is mixed with each part of fuel is called the air-fuel ratio. The air-fuel ratio is the weight of one part of a mixture compared to the other part in pounds. For example, 15 pounds of air mixed with 1 pound of fuel is an air-fuel ratio of 15:1. The mixture is made richer by adding more fuel or removing some air.

The air-fuel ratio for an average engine operating at normal cruising speed is about 15:1. When more power is needed or when the engine is at an idle, a richer mixture, such as 13:1 or 12:1, is required.

FIGURE 9. THROTTLE VALVE ASSEMBLY.



Probably the most important control on the carburetor is a device to change the amount of air-fuel mixture going to the engine. Without such a control, there would be no way of changing engine speeds. This controlling device is the throttle valve assembly, which is a round, flat disc mounted on a shaft. The throttle valve and shaft are near the bottom of the carburetor bore and in the path of airflow. The throttle valve shaft is connected by linkage to the accelerator pedal in the driver's compartment.

When the accelerator pedal is pushed all the way down, the throttle valve is wide open. The air-fuel mixture flows freely by the valve, and the engine can produce its greatest power and speed.

The engine is at idle speed when the valve is almost closed and only a small amount of air is allowed to pass the valve.

Lesson 1/Learning Event 2

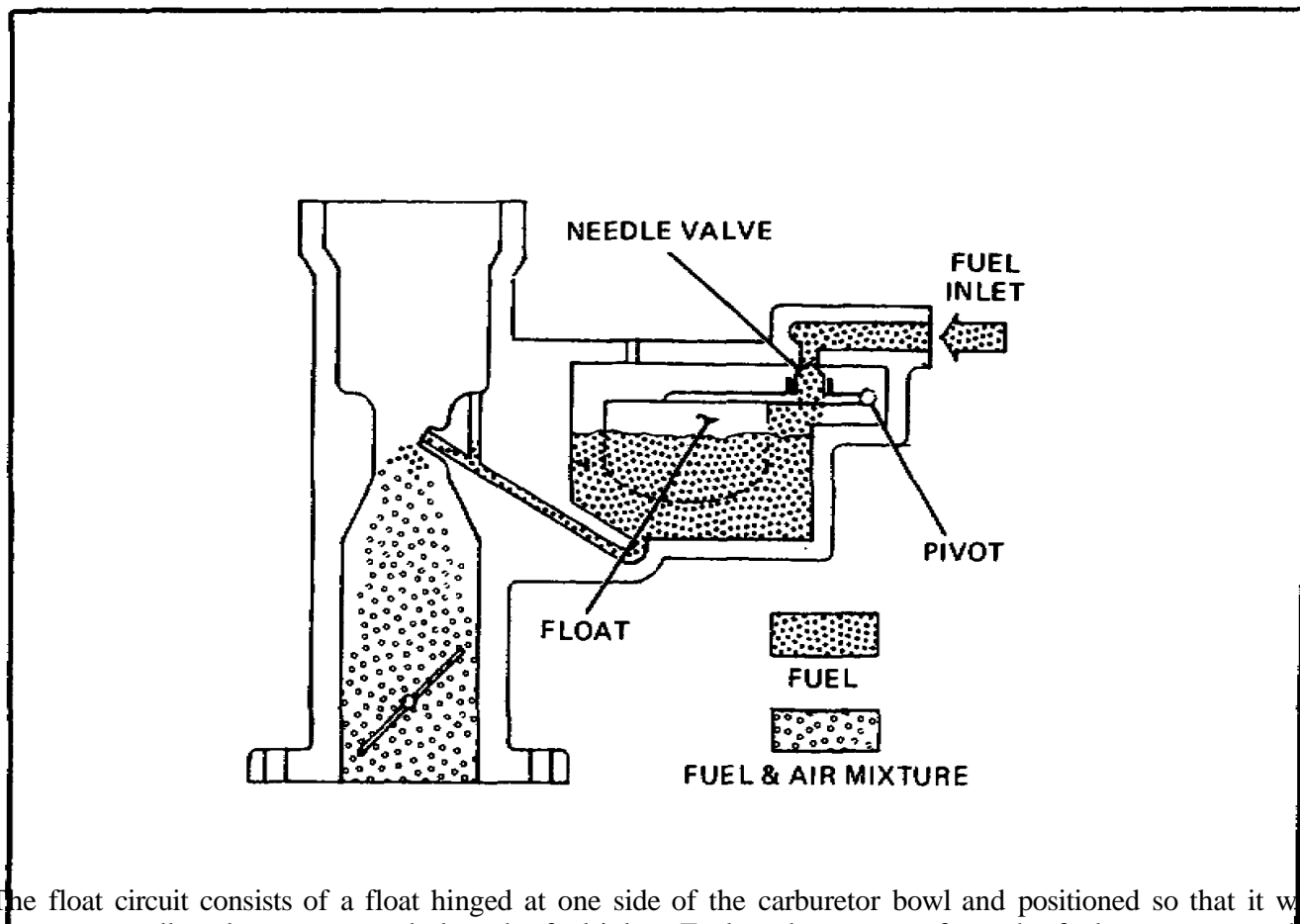
CARBURETOR CIRCUITS

Most carburetors have five circuits, or passages, for the fuel to flow to the venturi or to other points in the carburetor bore. These circuits are necessary because different engine operating conditions require different fuel-air mixtures.

The five carburetor circuits are the float circuit, the low-speed circuit, the high-speed circuit, the accelerating pump circuit, and the choke circuit.

The fuel in the carburetor bowl must be kept at a certain level whenever the engine is running. If the level is too high, too much fuel will be discharged through the nozzle. The engine will use too much fuel, and large deposits of carbon may form in the cylinders. If the fuel level is too low, the mixture will be too "lean" to operate the engine properly. The float circuit keeps the fuel at the correct level.

FIGURE 10. FLOAT CIRCUIT.

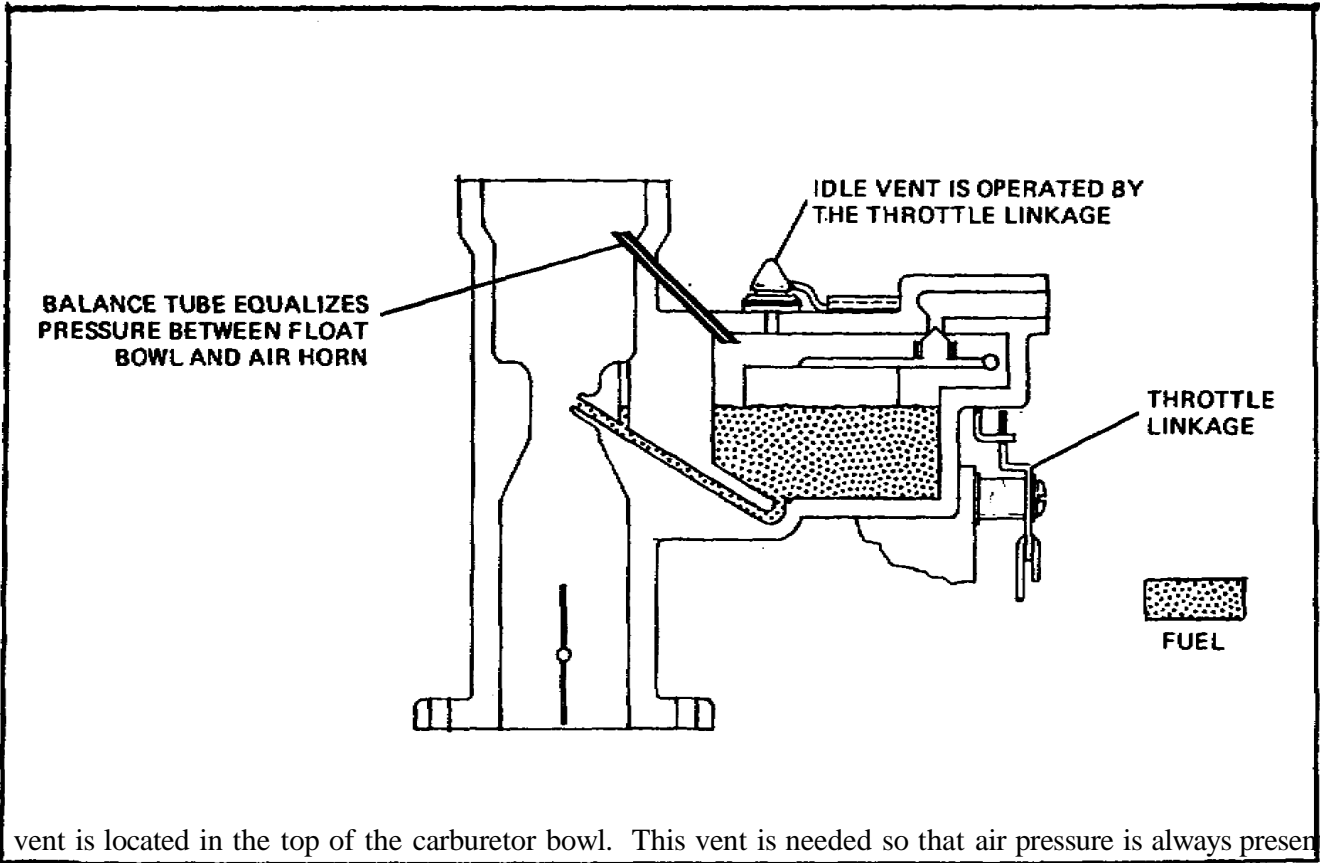


The float circuit consists of a float hinged at one side of the carburetor bowl and positioned so that it will operate a needle valve to open and close the fuel inlet. Fuel, under pressure from the fuel pump, enters the carburetor bowl at the fuel inlet.

When fuel enters faster than the engine can use it, the bowl fills up. This causes the float to rise, and it pushes the needle valve into its seat, shutting off incoming fuel. As the engine uses fuel, the fuel level in the bowl drops and the float lowers. The needle valve opens, and more fuel is allowed to enter.

In actual operation, the needle valve is very seldom closed. Instead, it stays open just enough so that balance is maintained on the fuel coming in the bowl and the fuel used by the engine.

FIGURE 11. CONTROLLING FUEL BOWL PRESSURE.



A vent is located in the top of the carburetor bowl. This vent is needed so that air pressure is always present on fuel in the carburetor bowl. (On military vehicles, this vent is usually connected to the inside of the carburetor air horn or to the air cleaner.)

When the throttle is almost closed, the amount of air flowing through the carburetor bore is so small that practically no vacuum is created in the venturi. Therefore, no fuel flows from the nozzle in the venturi. The low-speed circuit supplies fuel under this condition.

Lesson 1/learning Event 2

With the throttle closed, the engine creates a high vacuum below the throttle valve because the valve itself acts as a restriction. The low-speed circuit has an idle discharge hole below the throttle valve. The higher air pressure on the fuel in the carburetor bowl pushes the fuel to the vacuum at the idle discharging hole.

A small air-bleed hole is located at the top of the low-speed circuit passage. It lets air bleed into the circuit and mix with the gasoline. This helps atomize the fuel before it leaves the idle discharge port.

An adjusting needle valve is placed at the idle discharge hole. Turning this screw changes the richness of the idle mixture. Turning the screw inward closes the hole and allows less fuel to flow. With less fuel flowing, a leaner mixture is created. When the screw is turned outward, more fuel flows and the mixture is richer.

Opening the throttle a little above idle speed allows more air to pass the throttle valve. However, there is still not enough air passing through the venturi to get fuel to flow through the main discharge nozzle. More air is passing the throttle valve, so more fuel must be added to keep the mixture correct. To let more fuel in, a low-speed discharge port is added just above the idle discharge hole. As the throttle is opened slightly, its edge moves above the low-speed discharge hole. More fuel enters the airstream because it can now pass through two discharge holes. (In some carburetors, a long discharge slot is used instead of holes.)

The high-speed circuit includes the venturi, the main nozzle, and the high-speed jet. Usually, more than one venturi is used in a carburetor, with one placed inside the other. The main nozzle is centered in the smallest venturi. Fuel passes from the carburetor bowl to the main nozzle and flows through the high-speed jet. The hole in the jet is drilled to an exact size to meter the fuel flowing in the high-speed circuit.

In operation, the high- and low-speed circuits overlap. As the throttle is moved, each circuit continues working until after the next one begins. If there is no overlap between the circuits, the engine will run rough or even try to stop at certain throttle positions. This condition is called a flat spot in the carburetor.

When the engine is operating at cruising speeds, an air-fuel mixture of about 15:1 is being furnished for good economy and reasonable power. A power system in the high-speed circuit can enrich this mixture if necessary (to climb a hill or to operate at high speed).

Two types of power systems commonly used are the power jet and the metering rod.

In the power-jet system, the power-jet valve is controlled by a vacuum piston. When the throttle is closed, manifold vacuum is high. The vacuum piston is moved up against spring pressure, and the power-jet valve is closed. Opening the throttle to a point where more fuel is required lowers the manifold vacuum. Lower vacuum allows the piston to be pulled down by the spring pressure. This opens the power-jet valve, letting fuel flow through the power jet. This fuel bypasses the high-speed jet and increases the amount of fuel delivered into the airstream by the main discharge nozzle.

Metering rods are another way of enriching the fuel-air ratio to get more power. The metering rod is usually operated by linkage connected to the throttle valve. The rod has several steps or tapers on its lower end that pass through the high-speed jet. As the throttle is opened, the rod is lifted, so smaller steps are in the jet. This allows more fuel to pass through the jet, enriching the mixture.

Assume that a vehicle is moving down the road slowly. The throttle valve is practically closed, allowing only a small amount of air to pass through the carburetor venturi. The driver suddenly decides to pass a car ahead and slams the accelerator pedal to the floor. The throttle valve opens instantly. Air is very light in weight, so it increases its speed through the carburetor very quickly. Fuel is much heavier, and it will move slowly. Before the fuel and air flows become balanced, a very lean mixture is delivered to the engine. This causes the engine to backfire or hesitate. To prevent backfire or hesitation, the carburetor is equipped with an accelerating pump circuit. This circuit discharges a small amount of fuel into the airstream for a very short period of time when the throttle is suddenly opened.

One type of accelerating pump circuit consists of a pump cylinder, a pump piston that is operated by linkage connected to the throttle shaft, a fuel intake check valve in the bottom of the pump cylinder or well, a pump discharge check valve, and a pump discharge nozzle to spray the fuel into the airstream in the carburetor.

Lesson 1/learning Event 2

When the throttle is closed, the accelerator piston is in the up position. As the throttle is opened, the piston moves downward, pressurizing the fuel in the pump cylinder. The pump intake check valve closes, and the fuel in the pump well is forced out through the pump discharge valve and the pump nozzle in the carburetor bore.

If the pump piston is moved down suddenly, the fuel under it cannot be immediately discharged through the small discharge nozzle. For this reason, the operating linkage does not push directly on the piston. Instead, the linkage compresses the pump spring, and the spring pressure moves the piston down. This feature slows down the action of the pump and allows the fuel to flow out through the pump discharge nozzle for several seconds. The discharge tapers off as the movement of fuel in the main metering circuit increases. The accelerating pump circuit refills with fuel when the throttle closes. During the upward movement of the piston, the pump intake check valve opens, permitting fuel from the carburetor bowl to enter the pump cylinder.

Other accelerating pump circuits operate differently. One type makes use of manifold vacuum and spring pressure to operate the pump. Another type uses a pocket of air between the piston and fuel to eliminate the need for an accelerating pump spring.

It is a well-known fact that a richer mixture is needed when an engine is cold. This is because all the fuel supplied to the cylinders will not vaporize when cold. Therefore, a larger amount of fuel must be supplied to get enough vaporized fuel for combustion. To supply the extra fuel, a choke circuit is used.

The choke is a round, flat disc (similar to the throttle valve) in the carburetor air horn above the venturi. Closing the choke valve creates a high vacuum in the carburetor throat. This causes large amounts of fuel to flow freely from both the low- and high-speed circuits. Chokes may be operated manually by the driver, or they may operate automatically.

To operate a manual choke, the driver usually pulls a cable that closes the choke valve. Closing the valve completely shuts off the supply of air. However, gasoline must have some air in order to burn. The needed air is admitted by one of two methods.

One method is a choke valve that includes a spring-loaded poppet valve. The poppet is normally held in the closed position by a weak spring. As soon as the engine is cranked, a very high vacuum is created under the choke valve. This allows the higher outside air pressure to open the poppet valve and permit air to enter the engine cylinders.

In the manual method, the choke valve is operated by a coiled spring on the choke shaft. With the choke closed and the engine cranking, air pressure will overcome the spring tension and open the choke valve slightly to supply some air. As the engine warms up, the driver gradually opens the choke to supply a leaner mixture.

An automatic choke controls the air-fuel mixture for quick starting at any temperature. In addition, it provides the proper amount of choking during the entire engine warm-up period.

The automatic choke has a thermostatic spring and a vacuum piston to control the position of the choke valve. The spring tries to close the choke valve when the engine is cold, while the vacuum piston tries to open the valve. The choke valve is mounted off-center on its shaft, and any increase in air speed aids in opening the choke valve more.

The operation of the automatic choke depends on three factors: temperature, intake manifold vacuum, and speed of the air passing through the carburetor throat. Temperature change affects the thermostatic spring; as the spring is heated, it loses its tension and allows the choke to open.

When the engine is cold, the spring holds the choke valve closed. When the engine is started, vacuum from below the throttle valve is directed to the bottom of the vacuum piston. High vacuum under the piston causes the piston to work against spring pressure and partially open the choke. A small amount of air, heated by the engine exhaust, passes through the choke housing to heat the spring, allowing the choke to open as the engine warms up.

Different load conditions will also cause the position of the choke valve to change. A decrease in manifold vacuum will allow the spring to close the choke against pressure of the vacuum piston. An increase in air speed through the carburetor throat will force the choke valve open against tension of the spring.

Lesson 1/learning Event 2

MULTIBARREL CARBURETORS

Many carburetors, particularly on engines with more than six cylinders, have more than one barrel. Each barrel of a two-barrel carburetor has separate low- and high-speed circuits.

If the carburetor has four barrels, at least two barrels will have low-speed circuits and accelerating pump circuits. There are separate throttle valves for each barrel, but two of the valves are mounted on the same throttle shaft, causing two throttle valves to open or close at the same time.

The purpose of more than one barrel is to split the air-fuel mixture delivery to different cylinders between semi-independent carburetors. For instance, consider an eight-cylinder, V-type engine with a two-barrel carburetor. One barrel will take care of the two middle cylinders on the left bank and the two end cylinders on the right bank. The other barrel will take care of the remaining four cylinders. With such an arrangement, the intake manifold is divided into two sections, with each section delivering the fuel-air mixture to four cylinders.

Carburetors are often classified as up-draft, down-draft, or side-draft depending on the carburetor's position in respect to the intake manifold. If the carburetor is mounted below the manifold, it is classified as an up-draft carburetor. If it is above the manifold, it is a down-draft. When the carburetor and intake manifold are at the same level, the carburetor is a side-draft.

INTAKE MANIFOLD

When gasoline is vaporized rapidly, a natural refrigerating (cooling) process takes place. If you feel the outside of the carburetor throttle housing while the engine is running, the housing feels cool even though all the surrounding parts are very warm. This explains the frost that often collects around the carburetor and intake manifold during cold weather. The cooling action may cause the fuel vapors to condense into liquid drops.

Careful construction and design of the manifold reduces condensation. The intake manifold should be as short and as straight as possible to reduce the possibility of the fuel condensing before it reaches the cylinders. To assist in vaporizing the fuel, some intake manifolds have a section called the hot spot that is heated by exhaust gases.

Lesson 1/Learning Event 2

A valve is placed in the exhaust manifold that directs the flow of exhaust gases to the hot spot. A thermostatic spring controls the operation of this valve. When the engine is cold, the valve directs gases into the hot spot. As the engine warms up, the thermostatic spring loses its tension, and the gas pressure (aided by a weight) turns the valve so the hot gases do not enter the manifold hot spot.

On some vehicles, the heat control valve does not have a thermostatic spring. In this case, the valve is manually set to the OFF, INTERMEDIATE, or ON position depending on the weather and operating conditions.

Another method is to circulate the engine coolant around the manifold hot spot. This hot liquid, instead of the exhaust gases, heats the intake manifold.

Lesson 1/learning Event 3

Learning Event 3:

DESCRIBE THE PROCEDURES FOR INSPECTION OF GASOLINE ENGINE FUEL SYSTEMS

INTRODUCTION

The fuel system has only one purpose: To provide the proper air-fuel mixture in the proper amounts to the proper place at the proper time.

Each component in the system has to be operating properly for the fuel system to do its job. This is where you, the wheeled vehicle mechanic, fit into the picture. Your job on fuel systems will consist of ensuring that each component is doing its job.

To do this, you will have to know how to clean, tighten, test, adjust, repair, and replace fuel system components in a gasoline fuel system. We are now going to cover the inspection of these parts. The contents of this lesson are examples of the jobs you, as a unit maintenance mechanic, will do.

Keep in mind, always, when you are working on the fuel system, that gasoline is made to burn in the engine and not on it. Neither should it burn in the tank, on the floor, or on you.

Make sure the work area is kept free of spilled gasoline and that there are no sparks or fire in the area.

INSPECTION OF FUEL SYSTEM

Before any work is done on a fuel system, you must know what needs to be done. One way to find out is to inspect the system. This means look it over and see if you can find anything wrong. When inspecting, you should start at one end of the system (either end) and work step by step all the way through. Don't miss a thing.

We will start with the fuel tank on a 1/4-ton M151. The first thing you see on this is the filler neck cap, so let's take it off and take a good look at it. Two things you should look for are dirt and rust. Neither of these should be given a chance to get into the fuel tank because they can cause a lot of trouble. In fact, they probably cause more fuel system trouble than anything else, except possibly water. Another thing to look for on the cap is the retaining chain, which keeps the cap from being dropped and lost. Also, the gasket in the cap must form a good seal between the cap and the filler neck.

Lesson 1/Learning Event 3

Inspect the strainer inside the filler neck. It should be free of rust or dirt and have no holes, bends, kinks, or anything else that would make it unserviceable.

Now for the tank. It should be checked for such things as dirt, rust, and water on the inside. Check the outside for leaks, dents, and damage to the filler neck. Be sure the mountings are not loose. While you are at it, notice how much fuel is in the tank because this may be useful knowledge later.

Let's look on top of the tank. An item you should give some attention to is the sending unit. If you know how much fuel there is in the tank, that is what the fuel gage should show. If it doesn't, it could be the sending unit is at fault.

While you are at it, you'd better check the electrical connections, the gasket, and the mounting screws.

Another item at the tank is the fuel pump. Things you should check on it are, again, electrical connections, gaskets, and mounting screws. Another thing to check for on the pump is leaking fuel or vent line connections.

After checking the line connections at the fuel pump, check the fuel line all the way to the carburetor and the vent line to the air cleaner. You should look for such things as leaking connections and broken, bent, crimped, or leaking lines.

So far, you have covered the components from the tank filler cap to the carburetor. On the carburetor, you should look for leaks, cracks, insecure mountings, leaking gaskets, and loose or missing screws.

Next, inspect the linkage that controls the operation of the carburetor. When checking the accelerator linkage, you should look for missing or damaged parts, improper connections, and incorrect adjustment. On the choke linkage, you should check the cable condition, the cable stop, and cable adjustment (it should move the choke from the full open to the full closed positions). Also, check the cable operation and choke control mounting.

When the engine is operating, fuel will be flowing from the tank, through the lines, and through the carburetor. A lot of air must go through the air cleaner if the fuel system is to operate properly, so this must also be checked. Before you inspect the air cleaner, the cover must be removed. The things to look for

Lesson 1/learning Event 3

are dirt, the condition and amount of oil, clogged wire mesh, and holes in the oil reservoir. In addition, check it for secure mounting and the condition of the air hose, hose clamps, and all fittings.

Don't forget to check the intake manifold, too. It is part of the air-fuel system. To check the intake manifold gasket for leaks, put a small amount of oil around the intake manifold flanges with the engine running. If the oil is sucked into the manifold, the gaskets are leaking. Loose manifold bolts will also cause the gaskets to leak, so tighten them before blaming the gaskets. You should also look for excess dirt on the manifold and check for a cracked or warped manifold.

PRACTICE EXERCISE

1. When the bellows is fully expanded in the solenoid-operated fuel pump, it opens the
 - a. discharge valve.
 - b. contact points.
 - c. inlet valve.

2. The fuel tank vent lines used on military vehicles are connected to the
 - a. fuel filter.
 - b. air cleaner.
 - c. manifold.

3. The fuel pump most widely used on wheeled vehicle gasoline engines is the
 - a. mechanical, nonpositive, diaphragm type.
 - b. electric impeller type.
 - c. mechanical, positive, plunger type.

4. What is used to prevent main fuel lines from breaking from the vibration between the engine and the frame?
 - a. Clamps
 - b. Flexible hose
 - c. Copper tubing

5. What regulates the amount of pressure the diaphragm fuel pump can develop?
 - a. Rocker arm and link
 - b. Carburetor needle valve
 - c. Diaphragm spring

Lesson 1

ANSWERS TO PRACTICE EXERCISE

1. b (page 7)
2. b (page 3)
3. a (page 4)
4. b (page 3)
5. c (page 6)

LESSON 2
FUNDAMENTALS OF COMPRESSION IGNITION ENGINE FUEL SYSTEMS

TASK

Describe the fundamentals of compression ignition engine fuel systems.

CONDITIONS

Given information about the types, location, operation, and inspection of compression ignition engine fuel system components.

STANDARDS

Answer 70 percent of the multiple-choice test items covering fundamentals of compression ignition engine fuel systems.

REFERENCES

TM 9-8000

Learning Event 1:

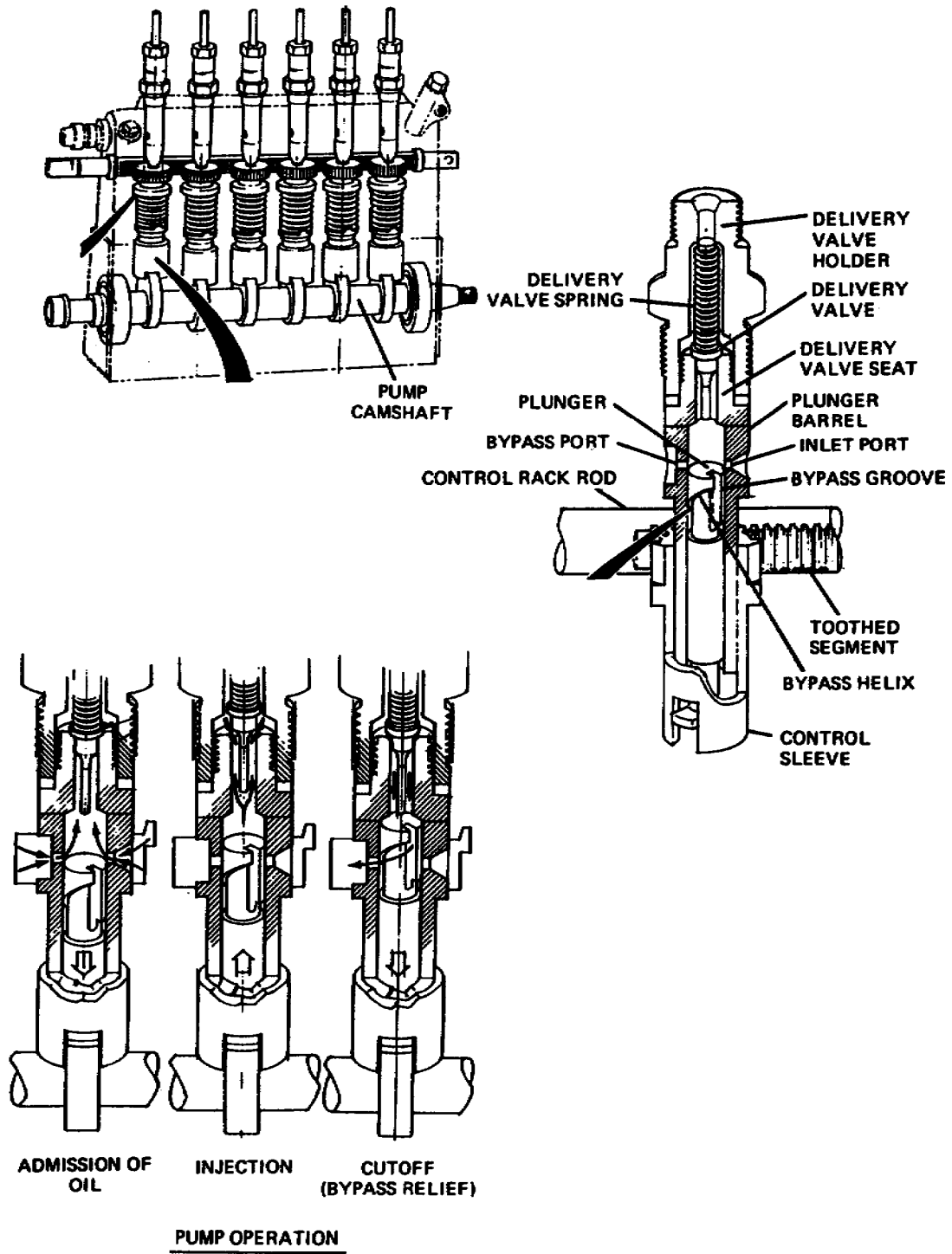
DESCRIBE THE COMPONENTS, PRINCIPLES, AND OPERATION OF FUEL INJECTION SYSTEMS

INTRODUCTION

The function of an injection system is to meter the fuel accurately, deliver equal amounts of fuel to all cylinders at a pressure high enough to ensure atomization, and control the start, rate, and duration of injection. Keep this threefold function in mind, and you will understand the operation of the various systems.

Diesel engines and some gasoline engines use fuel injection instead of carburetion. There are several types of fuel injection systems used on Army equipment: multiple-unit injection pump, unit injection, distributor injection, and pressure-time systems.

FIGURE 12. MULTIPLE-UNIT INJECTION PUMP.

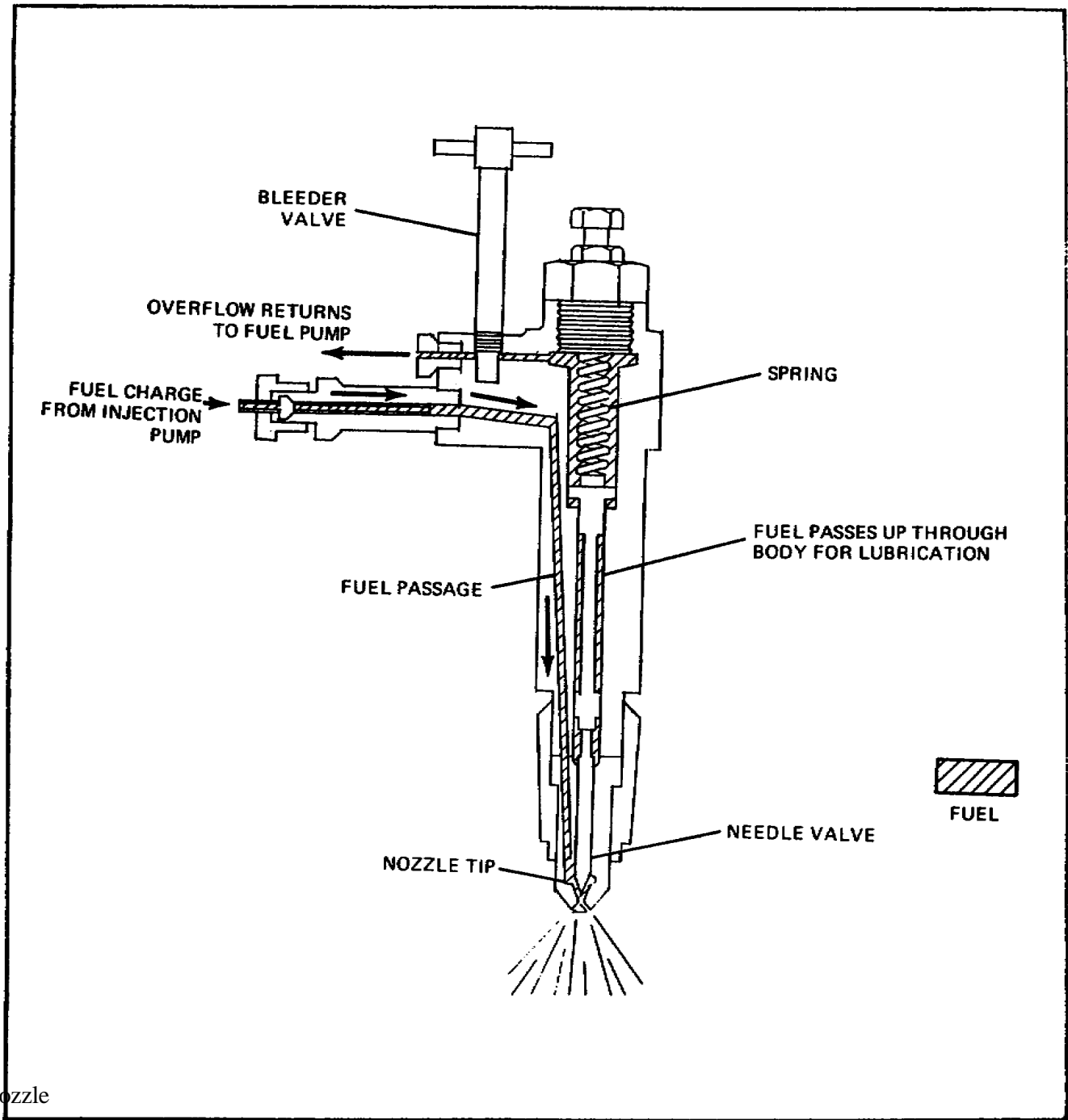


Multiple-Unit Injection Pump System

In the multiple-unit injection pump system, each cylinder has an individual injection pump which meters the fuel and delivers it under high pressure to the spray nozzle, which leads into the combustion chambers. The pumps are mounted in a common housing, are operated by a common camshaft, and use the same control mechanism to ensure an equal amount of fuel in each cylinder at the proper time.

Diesel fuel oil flows from the supply tank through a fuel filter to the fuel supply pump. The fuel supply pump forces the fuel through an additional filter to the injection pumps. The fuel injection pumps force a measured amount of fuel through high-pressure lines to the spray nozzle in the combustion chambers. Surplus fuel flows from the injection pumps through a check valve on the common housing and returns to the fuel supply tank.

FIGURE 13. MULTIPLE-UNIT INJECTOR.



Nozzle

For proper engine performance, the fuel oil must be injected into the combustion space in a definite spray form. This is accomplished by a spray nozzle, held in the correct position in the cylinder head by the nozzle holder.

The fuel delivered by the injection pump flows through the high-pressure line and enters the nozzle holder inlet. It passes through the edge filter, flows through the ducts in the holder and nozzle body, and flows down into the pressure chamber of the spray nozzle above the valve seat.

There, the pressure of the fuel oil acts on the differential area of the nozzle valve. At the moment when the pressure of the fuel exceeds the pressure exerted by the adjusting spring, the nozzle valve is lifted off its seat and the fuel is forced through the orifice and sprayed into the combustion chamber of the engine. The nozzle valve returns to its seat after the injection pump has ceased to deliver fuel. The hydraulic opening pressure of the spray nozzle may vary from 1,000 to 4,000 PSI, depending on engine combustion chamber requirements.

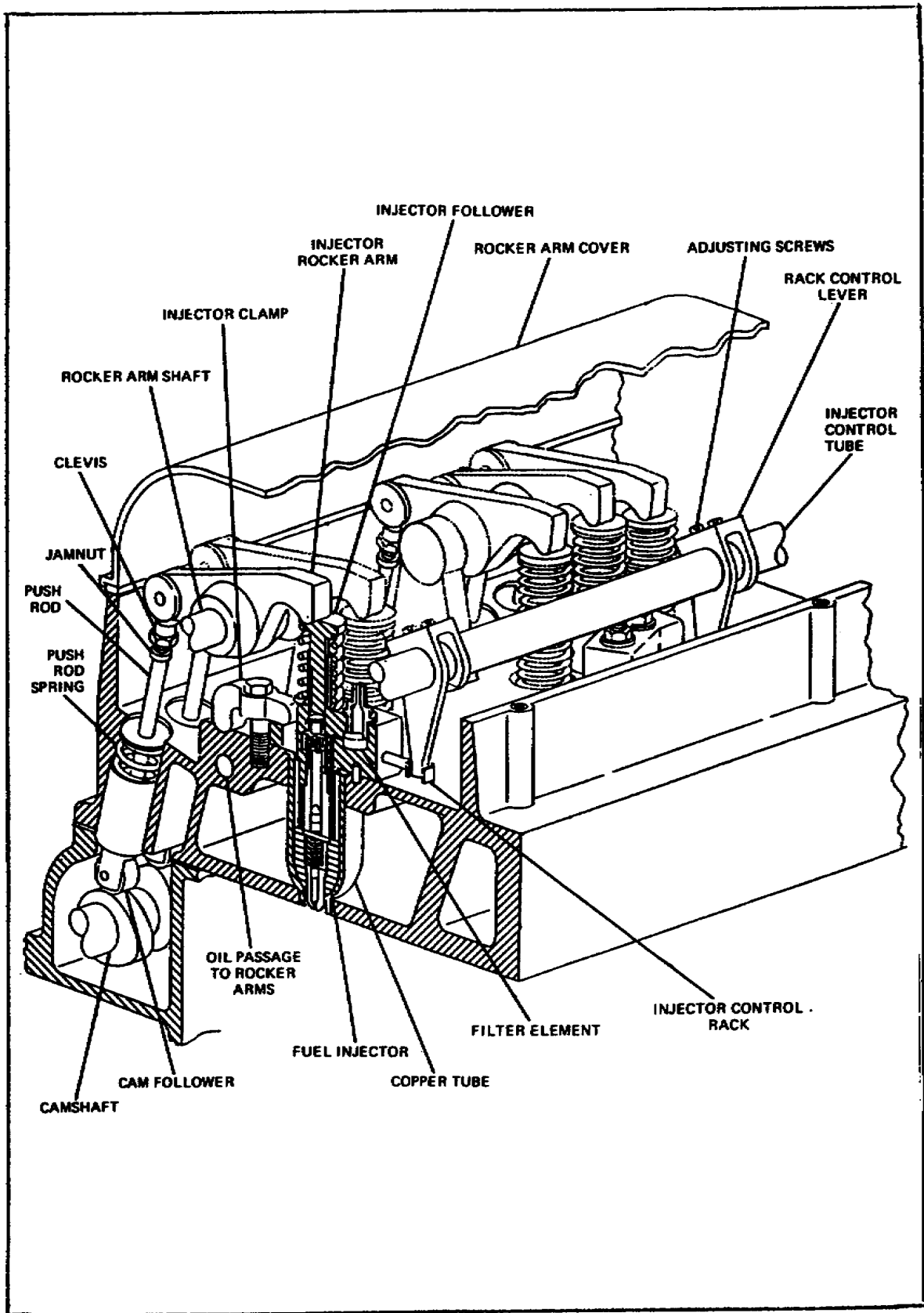
Because of the widely differing shapes of the fuel spray for various combustion chamber designs and because of the wide range in engine power demands, a variety of nozzles are used with multiple-unit injection pump systems. Essentially, there are two basic groups: pintle nozzles and hole nozzles. Pintle nozzles are generally used in engines with precombustion, turbulence, or divided chambers. Hole nozzles are generally used with open combustion chamber designs.

Nozzle holder

The nozzle holder holds the spray nozzle in its correct position in the engine cylinder, provides a means of conducting fuel oil to the nozzle, and conducts heat away from the nozzle.

Lesson 2/Learning Event 1

FIGURE 14. UNIT INJECTION SYSTEM.



Unit Injection System

This system consists of injectors, fuel supply pump, fuel oil filter, and the fuel oil manifold.

Fuel is drawn from the supply tank through the primary filter by the fuel supply pump. From the pump, fuel is forced through the secondary filter and to the fuel intake manifold which supplies the injectors. Surplus fuel, flowing through the injectors, is returned through the fuel outlet manifold to the supply tank.

Unit injectors combine the injection pump, the fuel valve, and the nozzle in a single housing to eliminate the high-pressure line.

These units provide a complete and independent injection system for each cylinder and are mounted in the cylinder head, with their spray tips slightly below the top of the inside surface of the combustion chambers. U-clamps, bolted to the cylinder head and fitting into a machined recess in each side of the injector body, hold the injector in place in a water-cooled copper tube which passes through the cylinder head. The tapered lower end of the injector seats in the copper tube, forming a tight seal to withstand the high pressures inside the cylinder.

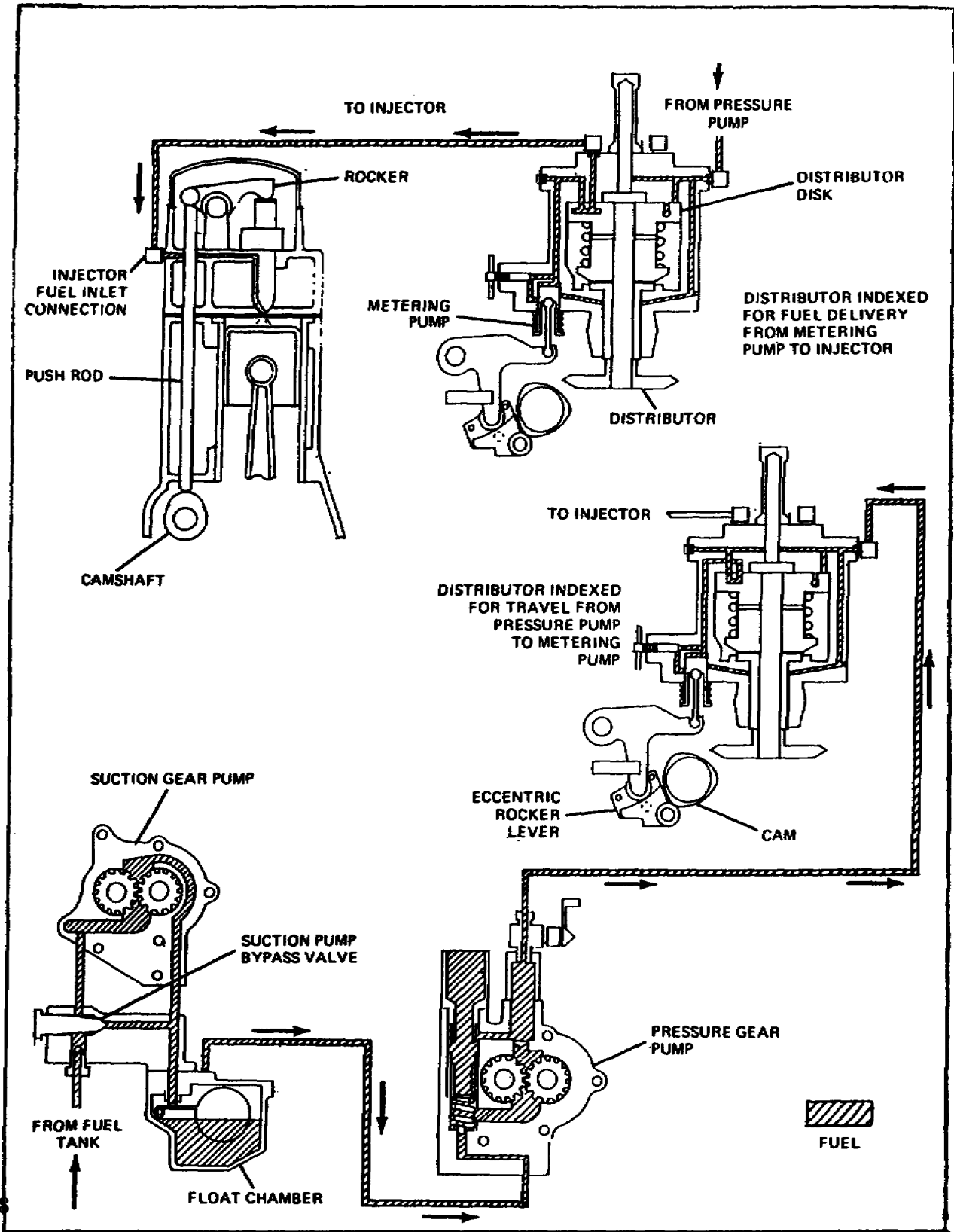
Fuel oil is supplied to the injector at about 20 PSI and enters the body at the top through the filter cap. After passing through the fine-grained filter element in the inlet passage, the fuel oil fills the annular (ring-shaped) supply chamber between the bushing and split deflector. The plunger operates up and down in the bushing, the bore of which is connected to the fuel supply in the annular chamber by two funnel-shaped ports, one on each side at different heights.

Injector rocker arms

The injector arms are actuated through pushrods from the engine camshaft. The motion of the injector rocker arm is transmitted to the plunger by the follower, which bears against the return spring. In addition to this reciprocating motion, the plunger can be rotated in operation around its axis by the gear, which is in mesh with the control rack.

Each injector control rack is connected by a joint to a lever on a common control tube which, in turn, is linked to the governor and throttle.

FIGURE 15. DISTRIBUTOR INJECTION SYSTEM.



Distributor Injection System

This system, used in automotive diesel engines, is classed as a low-pressure system: Pumping, metering, and distribution take place at low pressure. The high pressure required for injection is built up in the injector at each cylinder. A suction gear pump lifts fuel from the tank and delivers it to the float chamber, from which a second gear pump delivers it, at low pressure, to the distributor. Fuel passes through the distributor to the metering pump, then through the distributor again, and on to the injector where it is injected into the cylinder.

Distributor

The distributor consists of a rotating disk and a stationary cover which are connected to fuel lines running to individual injectors. The disk and cover have a series of holes which, when properly indexed, form passages from the fuel supply pump to the metering pump. The metering plunger moves down on its suction stroke and permits the barrel to fill with oil. The disk continues to rotate and lines up with the correct discharge hole in the cover just as the metering plunger rises by action of the main fuel pump cam. This forces the fuel into the proper injector line.

Metering pump

The metering pump is a closely fitted reciprocating pump. Its motion is caused by a link from the plunger lever. The plunger lever is operated by a vertical lever controlled, in turn, by an eccentric rocker lever running directly off a cam on the fuel pump main shaft. The position of the vertical lever in the eccentric of the rocker lever determines the travel of the plunger lever and, consequently, the travel of the metering plunger.

As the metering plunger starts upward on its controlled stroke, it pushes fuel to the injector through passages formed by the rotating distributor disk. The stroke of the metering plunger, which determines the amount of fuel going to each injector, is varied by changing the position of the vertical lever between the stop pins in the cam rocker lever.

Injector

The injector consists of a forged body with a fitted plunger. This plunger is forced down against spring action by a rocker arm actuated by pushrods from the engine camshaft. Mounted on the end of the body is the cup which contains the nozzle tip. On the

Lesson 2/Learning Event 1

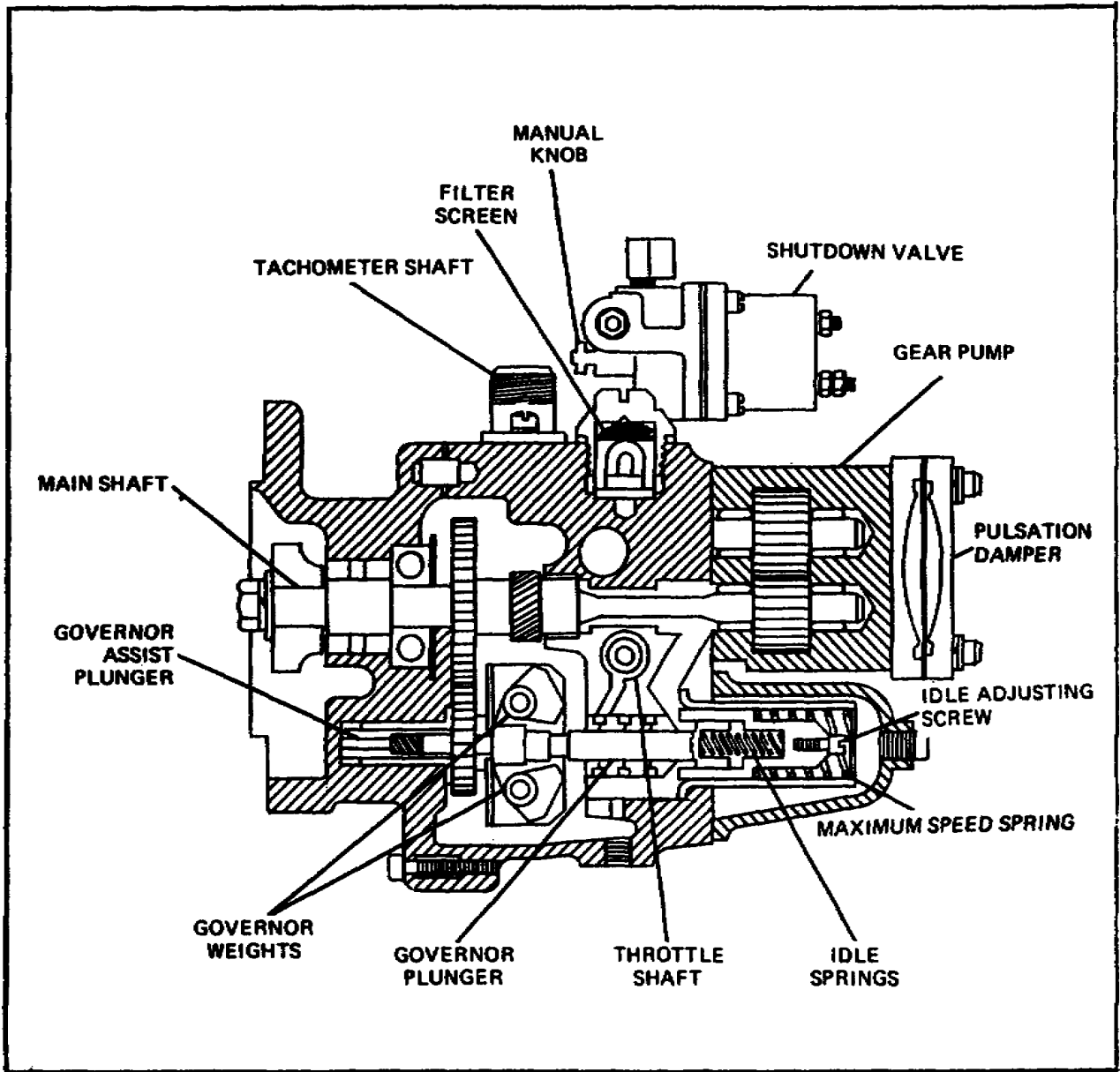
intake stroke of the engine, the fuel metering pump forces a charge of fuel of the exact amount for the load and speed of the engine into the cup.

Pressure-Time System

This system operates on the principle that changing the pressure of a liquid flowing through a pipe changes the amount of liquid coming out the open end. (Increasing the pressure increases the amount of liquid delivered.)

The pressure-time system consists of the fuel pump (with governor), the supply and drain lines, and the injectors.

FIGURE 16. PRESSURE-TIMED GEAR PUMP.



Fuel pump

The fuel pump is made of three main units: a gear pump, a pressure regulator, and a governor and throttle.

- Gear pump - draws fuel from the supply tank and delivers it under pressure through the pump and supply lines to the individual injector.
- Pressure regulator - limits the pressure of fuel to the injector.
- Governor and throttle - act independently of the pressure regulator to control fuel pressure to the regulator.

Injectors

Fuel circulates through the injector at all times, except during a short period following injection into the combustion chamber. From the inlet connection, fuel flows down the inlet passage of the injector, around the injector plunger, between the body end and cup, up the drain passage to the drain connections and manifold, and back to the supply tank.

As the plunger comes up, the injector feed passage is opened and fuel flows through the metering orifice into the cup. At the same time, fuel flows past the cup and out the drain orifice. The amount of fuel entering the cup is controlled by the fuel pressure against the metering orifice, and fuel pressure is controlled by the fuel pump. During injection, the plunger comes down until the orifice is closed, and the fuel in the cup is injected into the cylinder. While the plunger is seated in the cup, all fuel flow in the injector is stopped.

SUPPLY PUMPS

Fuel injection pumps must be supplied with fuel oil under pressure, because they have insufficient suction ability. Therefore, all injection systems require supply pumps to transfer fuel from the supply tank to the injection pump. Pumps for this purpose have a positive suction lift, and their performance is independent of any normal variations in viscosity, pressure, or temperature of the fuel. The pumps in use today are gear, plunger, and/or vane types.

Lesson 2/Learning Event 1

GOVERNORS

Engine speed in a diesel engine is controlled by the amount of fuel injected; consequently, the injection system is designed to supply the maximum amount of fuel which will enable the engine to operate at full load and reach a predetermined maximum speed (RPM). However, if the maximum fuel charge is supplied to the cylinder when the engine is operating under partial load or no load, the engine will overspeed and soon cause failure.

All diesel engines require governors to prevent overspeeding of the engines under light loads. Automotive diesel engines also demand control of the idling speed. Governors provide variable speed control. Besides controlling minimum and maximum speeds, they will hold any intermediate speed desired by the operator.

Learning Event 2:

DESCRIBE THE PRINCIPLES AND OPERATION OF COMPRESSION IGNITION
ENGINE AIR INDUCTION SYSTEMS

AIR INDUCTION (NATURALLY ASPIRATED)

The power developed by a naturally aspirated internal combustion engine is dependent upon the density of the air inducted into the engine. In a naturally aspirated engine, the air is drawn into the cylinder on the intake stroke with a force acting upon the gas equal to the pressure difference between the atmosphere and the cylinder pressure. The cylinder pressure approaches that of a perfect vacuum, which is 0 pressure. Atmospheric pressure is about 15 PSI. Therefore, the pressure forcing the air into the cylinder is about 15 PSI.

The highest density that can be attained is atmospheric air density; but this is not usually attained because of certain losses in internal combustion engines: leakage past the piston, pressure drops across restrictions in the manifold, leakage in the valves, and also the heating of the air as it enters the manifold (which tends to expand the gas and decrease its density).

All of these losses make it hard for the engine to breathe. This causes slow response when the accelerator is depressed and reduces torque output before maximum power output. As engine speed is increased, the "breathing" of the engine becomes more difficult, because each cylinder has a shorter time to fill itself with air-fuel mixture.

SUPERCHARGING

Supercharging is assistance given to the air intake process by use of supplementary fans, blowers, and compressors. Supercharging greatly increases the power output of an engine with very little increase in weight. A supercharger accomplishes this by increasing the overall efficiency of the engine.

Overall efficiency of an internal combustion engine is affected by many factors. One factor is "volumetric efficiency." Volumetric efficiency can be defined as the ratio of the weight of the air actually drawn into the engine over a definite period of time to the weight of the air that would be drawn in without the losses present in any engine, such as leakage, friction losses, heat-transfer losses, and so forth.

Lesson 2/Learning Event 2

(The term "volumetric" efficiency is slightly misleading because engine efficiency is actually a ratio of weights and not "volumes." However, when this term is used in connection with pumps and compressors, the ratio is of volumes, and this term has become applied to engine efficiency also.)

Properties of Gases and Their Relation to Supercharging

A review of mass, volume, and density, as applied to gases, is necessary to explain the principle of supercharging.

All matter can be classified into solids and fluids. Fluids are, in turn, subdivided into liquids and gases. The weight of any substance depends upon its density, and the density of solids and liquids may be considered to be essentially constant. This is not the case with gases, for the density of gases is proportional to the pressure applied. In other words, when the pressure upon a gas is increased, its density will also increase. Therefore, two identical volumes of gas under different pressures will not weigh the same. For example, at sea level, 13 cubic feet of air weighs one pound, but at high altitudes where the atmospheric pressure is lower, the same 13 cubic feet of air weighs a good deal less.

Mass, weight, and volume. To an engineer, mass has a different meaning than weight, but in general, the two may be considered the same. "Volume" refers to the space occupied by matter, and "weight" refers to the force which a certain volume of matter would exert on a scale. The weight of any substance is directly proportional to its density and volume.

Boyle's law. The volume of a gas can be reduced by applying pressure. This is known as compression. Boyle's law states: The volume of an ideal gas is inversely proportional to the pressure upon it, if temperature is maintained constant. (There is no "ideal" gas, but air conforms closely and is considered ideal.)

Air Induction in Supercharged Engines

A supercharger is essentially a pump whose main function is to compress the air or air-fuel mixture to increase the density of the charge. A supercharger increases the power output in two ways.

- It increases the density of the air-fuel mixture delivered to the cylinders of the engine.
- It increases the maximum compression pressure.

The compression ratio for any engine is constant. The greater the pressure at the beginning of the compression stroke, the greater will be the pressure at the end of the stroke. Higher compression increases the power output of the engine, because the burning temperature of the gases is higher; therefore, more energy is released per stroke of the engine.

SUPERCHARGER SYSTEMS AND PUMPS

Types of drives

Two means of driving supercharger pumps are used. In one system, escaping exhaust gas is used to drive a turbine that is coupled to a supercharger impeller pump; this is called a turbosupercharger. The second method is a mechanical drive, powered by a gear train from the engine.

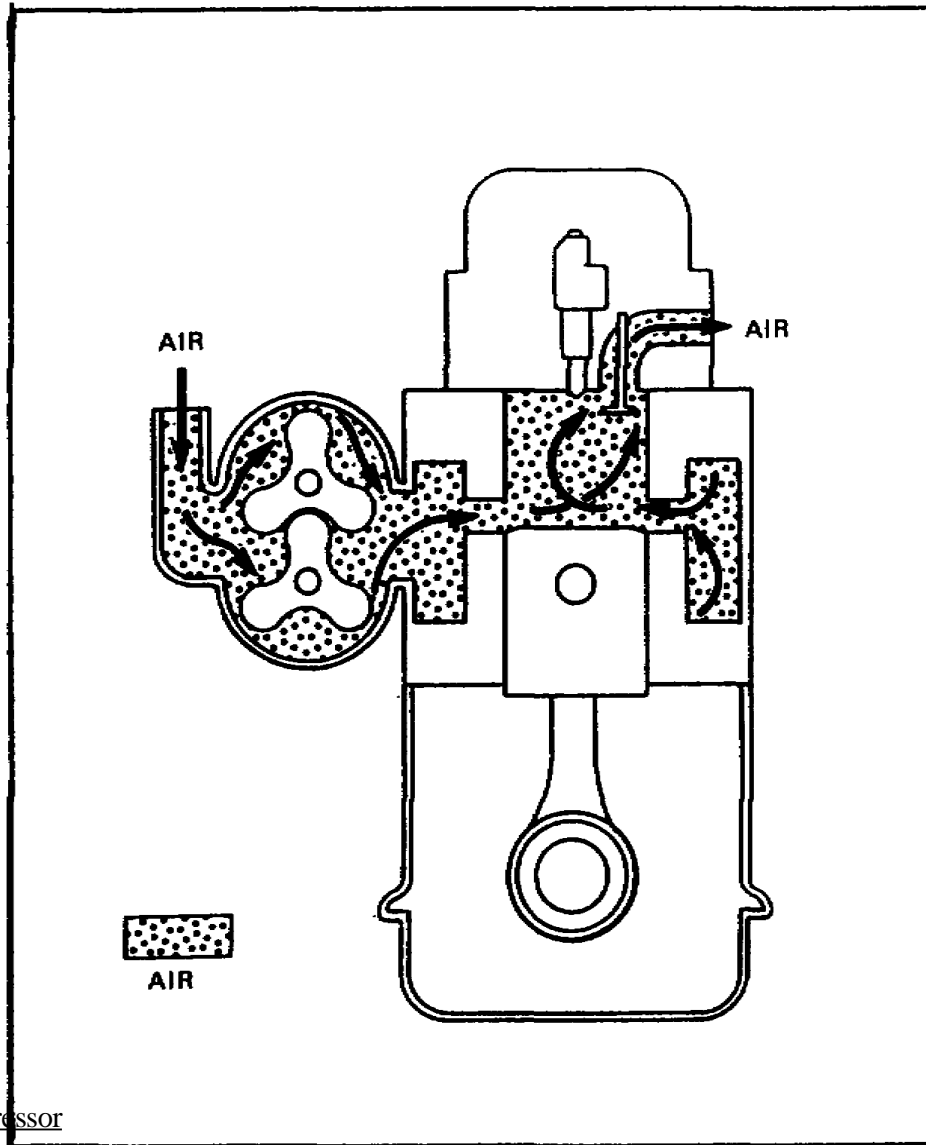
Types of pumps (compressors).

There are four basic types of compressors: diaphragm, reciprocating, rotary, and centrifugal.

Diaphragm and reciprocating types are not used in supercharging because of the limited amount of air that they can handle. Rotary and centrifugal compressors have no reciprocating parts, and large volumes of air can be handled per unit of time. For this reason, only rotating compressors (rotary and centrifugal) can be used for supercharging.

ROTATING COMPRESSORS

FIGURE 17. ROOTES SUPERCHARGER.



Rootes-Type Compressor

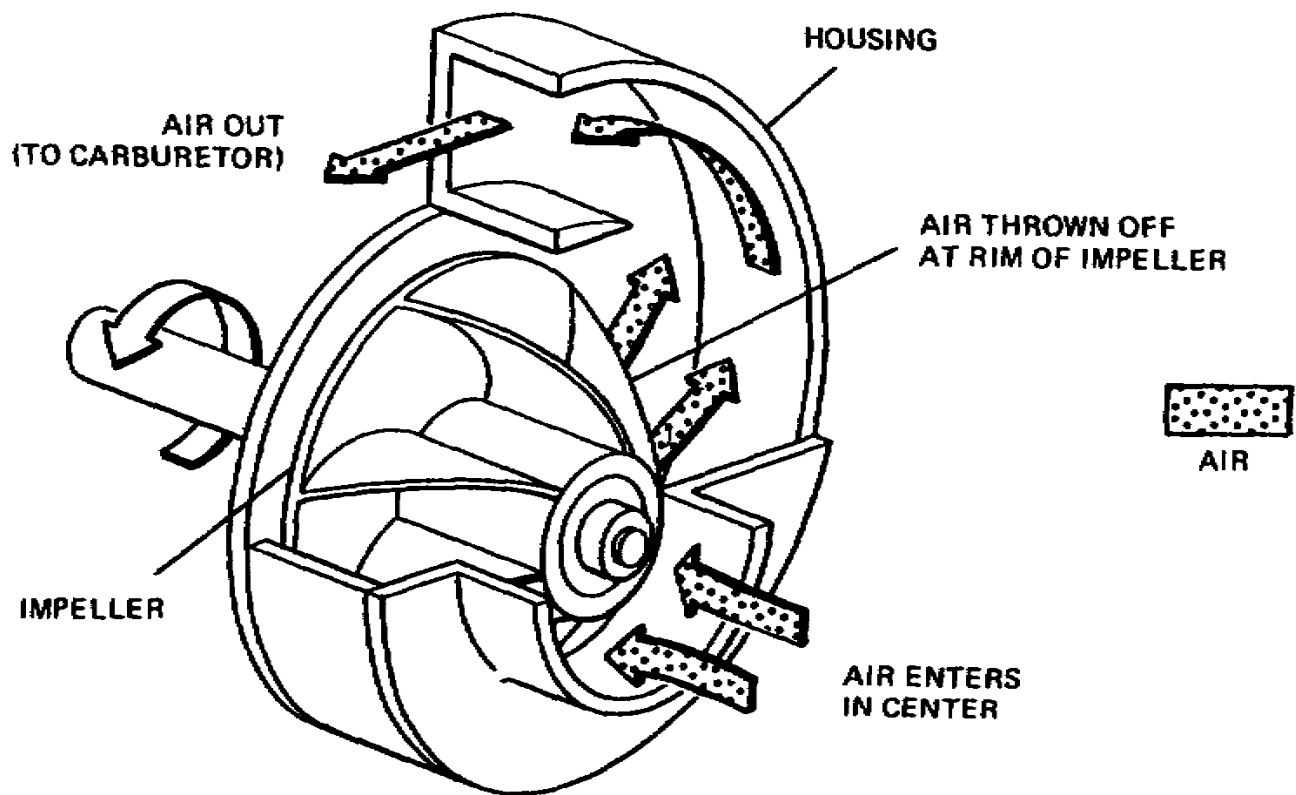
The Roots compressor, or blower, was designed especially for efficient diesel operation. It supplies the fresh air needed for combustion and scavenging in two-cycle diesel engines. Its operation is similar to that of a gear-type oil pump.

In the scavenging process, a charge of air is forced into the cylinder by the blower and thoroughly sweeps out all of the burned gases through the exhaust valve ports. This air also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, after scavenging, each cylinder is filled with fresh, clean air for efficient combustion.

The air entering the blower from the air cleaner is picked up by the blower rotor lobes and carried to the discharge side of the blower. Continuous fresh air from the blower enters the air chamber of the cylinder block and sweeps through the intake ports of the cylinder liners. The angle of the ports in the cylinder liners creates a uniform swirling motion to the intake air as it enters the cylinders. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

CENTRIFUGAL COMPRESSOR

FIGURE 18. CENTRIFUGAL SUPERCHARGER.



The centrifugal supercharger, or turbocharger, is a nonpositive-displacement type compressor of high output capacity. The impeller is installed in the air inlet, is usually made of an aluminum-alloy forging, and is designed to withstand high centrifugal forces of rotation. It is balanced accurately to reduce vibration. The radial vanes of the impeller catch the air, and the air is centrifugally forced through the radial passageway formed by the vanes.

Lesson 2/Learning Event 2

Compression increases as the air is whirled from the center outward, and more air rushes in to fill the void at the center. The compressed air occupies a progressively smaller volume as it travels from the hub, and the velocity of the air decreases in passing from the hub to the perimeter, Decrease of velocity with rise in pressure is called diffuser compression.

There are three steps in compression in a centrifugal supercharger. These are caused by centrifugal action, diverging contours at outer perimeter, and action of the diffuser plate.

Learning Event 3: DESCRIBE THE PROCEDURES FOR INSPECTION OF COMPRESSION IGNITION ENGINE FUEL SYSTEMS

INTRODUCTION

You now know the many differences in construction and operation between the fuel systems of compression ignition and spark ignition engines. There are also a lot of differences in the maintenance procedures performed on the two systems. As a rule, maintaining the fuel systems of compression ignition engines requires even more knowledge and skill than spark ignition systems. Mechanics who are capable and well trained on this are in great demand, so it will be to your advantage to put forth extra effort on the subject. It is true that most of the major maintenance on compression ignition fuel systems will be done by fuel and electrical systems repairers, but there are many things to be done by an organizational repairer. For instance, you, as a wheeled vehicle mechanic working at organization level, may be called upon to do any of the following: inspect, test, service, clean, tighten, and make some adjustments or even replace some components of the fuel and air induction systems.

The work done by you will be detecting and repairing troubles while they are small, before they have a chance to cause serious problems. Indeed, this is the most important part of all maintenance!

INSPECTION OF COMPONENTS

You will probably do more work on multifuel systems than on diesel fuel systems, so the major part of this lesson will deal with maintenance of air-fuel systems of the 2 1/2-ton trucks, M35A1 and M35A2, which are powered by multifuel engines. The following is how you should go about the job of inspecting the air-fuel systems of these trucks:

Start by inspecting the fuel tank for holes, rusty spots, and improper mounting. If the tank has a rusty spot or if some other part is rubbing against the tank, a leak will soon develop. Inspect the filler cap to make sure it seals the filler neck and that it is held by its retaining chain. Check the condition of the filler neck and the fuel strainer. Make a visual check of the fuel gage sending unit and fuel pump electrical connections. Check for any damaged or leaking fittings and connections.

Lesson 2/Learning Event 3

Trace the fuel feed, fuel return, and vent lines along the frame. Make sure they are not broken, leaking, bent, crimped, or damaged in any way. Make sure the lines are clipped securely to the frame so that they won't break from vibration or wear holes by rubbing against nearby parts.

As you trace the fuel line, you will come to the primary fuel filter which is mounted to a frame bracket under the engine generator. Check the filter closely for insecure mounting, leaks, and damage. Open the drain valve on the bottom of the filter and watch for any dirt or water. Always catch drained fuel in a container and dispose of it properly so that you will not cause a fire hazard.

If any dirt or water is found in the primary filter, drain the secondary filter. If any is found in the secondary filter, drain the final filter. Both the secondary and final fuel filters are mounted on the left rear of the engine. When a large amount of dirt or water is found in the filters (especially the final filter), clean the primary filter and replace the secondary and final fuel filter elements.

Inspect the fuel injection pump, operating linkage, and connecting lines for improper mounting, external damage, and leaks. Since engine lubricating oil is used in the injector pump, you will have to be on the lookout for oil leaks as well as fuel leaks while you inspect the injector pump. Also inspect the condition of the protective dust caps at the high-pressure outlets of the injection pump hydraulic head. Use extreme caution when checking for leaks or working near high-pressure fuel lines. The fuel is under enough pressure to puncture your skin and could cause blood poisoning. Keep your hands away from suspected leaks while the engine is running.

Inspect the high-pressure lines, fuel injector nozzles, and fuel return lines for damage, leaks, and improper mounting. Use a wrench to check the fuel injector nozzle mounting bolts for looseness. Loose bolts should be tightened with a torque wrench.

Move to the opposite side of the engine compartment and inspect the air induction system. Check the air intake or rain hood for excess dirt, and check the air intake flexible tube for condition. Make sure that the flexible tube does not leak. Check the air cleaner mounting bolts for tightness.

Release the air cleaner body-to-base mounting clamps, and remove the body from the base. Check the condition of the rubber seal and the mounting clamps to make sure that the base seals air-tight against the cleaner body. Check the filter element for excess dirt, evidence of water, hardening of the filter material, and for any external damage.

Make sure that you look over the entire fuel and air intake systems for anything that seems to be wrong. Look for broken parts, loose or worn parts, and leaks. Also look for anything that indicates a part which may be in trouble or may be causing trouble. This is another method of learning symptoms that may help you locate trouble.

If the engine will run, start it and look for leaks around the fuel lines and connections. This is known as an "operational" or functional inspection.

Remember, you have five senses that can help you locate trouble. For example, you can SMELL fuel or you might SEE it leaking. You might HEAR the air whistling as it leaks into a hole in the air cleaner hose or past a loose hose.

INSPECTING A MALFUNCTIONING VEHICLE

Once you have learned all that you can, look over the "symptoms" reported on this vehicle. See if they point to any part that may be defective or may be causing the trouble. Let's say that the truck has lost power. Another symptom, learned from the driver, is that it was using more fuel than normal. These two symptoms point out that the engine is either getting too much fuel or not enough air. One of the more probable causes in this case is a partially plugged air cleaner.

However, don't start removing parts! Don't be hasty and replace parts until all symptoms have been considered.

Symptoms that show up in engine power, fuel consumption, and the exhaust system can all be caused by a faulty air intake component. A poor troubleshooter may try to stop the engine from using too much fuel by repairing or replacing parts in the fuel system.

The main thing is to try to find out what is actually causing the trouble. This is called "diagnosing the symptoms" and "isolating the fault."

Lesson 2/Learning Event 3

Another trouble that you might find is that the engine stops because of no fuel being injected into the cylinders. This could be caused by many different conditions. Let's see how to proceed to locate the cause of this trouble.

Remember, don't start removing parts. Make a good visual inspection of the fuel system first, to include checking that there is fuel in the fuel tank. Make sure the fuel lines are not cracked or broken.

Examine the linkage to the fuel injector pump. The accelerator linkage could be disconnected and, with the idle speed adjustment set wrong, the cylinders would be out of fuel. Another linkage item that could cause this trouble is the fuel shutoff control. Make sure it is not improperly adjusted. Check to see if the shutoff control cable housing has slipped rearward out of the clip on the fuel injector pump. This condition can cause the trouble, as it has the same effect as pulling out the control in the cab.

If you cannot see anything wrong, check to see if the fuel lines are open from the tank to the fuel injector pump. This can be done by first disconnecting the fuel line at the inlet side of the injector pump hydraulic head. Then, turn on the accessory switch and see if fuel is pumped from the tank through the line. Make sure you catch the fuel in a suitable container.

In the above inspection, you are finding out if the lines are not plugged and if the in-tank pump is operating. If the fuel does not flow out of the disconnected line, the trouble has to be back toward the tank. If the fuel does flow, the trouble must be in the fuel injector pump high-pressure lines or injector nozzles.

If no fuel flows, there could be many reasons. The lines and filters could be plugged, or the in-tank pump might not be operating. If you listen, close to the tank, you can hear the in-tank pump humming when it is operating. If the in-tank pump is operating, you can check its pressure. If the in-tank pump does not operate, check out the electrical circuit to the pump.

If the in-tank pump is operating as it should, but no fuel reaches the injector pump, the trouble can easily be located. With the in-tank pump running, loosen the fittings on the fuel lines or open the bleed valves, one at a time, to see if fuel will flow out. Start at the final stage (engine secondary filter) and work toward the tank. Let's say that fuel leaked when you loosened the fitting on the tank side of the vehicle primary filter. However, no fuel leaked from the fitting on the engine side of the filter. This indicates the trouble is in the filter. It's probably stopped up and needs cleaning.

If fuel reaches the injector pump and the linkage is all right, the problem must be in the injector pump or the injector nozzles and lines. You are authorized to replace the high-pressure lines; however, it is unlikely that they are all plugged. The next step would be to notify your support unit of the condition.

Another problem you may find in the fuel and air intake systems is an improper fuel-air mixture. A clogged air cleaner can cause smoky exhaust and low engine power. It can also cause the truck to use too much fuel-air mixture in the combustion chamber. The mixture is too rich (does not have enough air). Let's see what else can cause an improper mixture of air and fuel.

On some 2 1/2-ton, multifuel engines, a turbosupercharger helps supply air to the engine cylinders. If the turbosupercharger is defective, the fuel-air mixture becomes too rich, especially at higher engine speeds. A defective turbosupercharger will generally show the same symptoms as a clogged air cleaner. This includes smoky exhaust, low power, and use of too much fuel. You should check the air cleaner first when these symptoms appear.

If the air cleaner element is not clogged, check the manifold heater gaskets for leakage. The gaskets could be blown, or the manifold heater elbow could be loose. Any leak in this area will decrease the turbosupercharger output and cause the fuel-air mixture to be too rich.

If the manifold heater gaskets are not leaking and the air cleaner is not clogged, the fault is in the turbosupercharger. You should notify your support maintenance unit because you are not authorized to test, remove, or replace the turbosupercharger.

High fuel consumption is a problem that you should look into as soon as possible. This problem may not seem important; however, the driver and other personnel aboard may be riding a very unsafe vehicle!

Lesson 2/Learning Event 3

When a vehicle uses too much fuel, the first thing to look for are LEAKS! If the driver says that the engine develops full power but uses too much fuel, it's a good possibility that this is what is wrong. Much of the fuel system is on the right side of the vehicle, and the hot exhaust system is there also. So, you can see the danger.

While you are looking for leaks, make sure all fuel line fittings are tight. If no leaks are found, turn on the in-tank pump and recheck for leaks. Start the engine and check for leaks.

Check the air intake system for a blockage, such as a clogged air cleaner. (Remember, a restricted air intake system generally causes black exhaust and low power.)

The engine will also use too much fuel if the injector pump is out of time or is improperly adjusted. Generally, when the engine is out of adjustment, it will also be low on power. If this seems to be the trouble, notify your support maintenance unit.

The manifold flame heater aids in starting the multifuel engine when it is cold. If you have trouble starting the engine even with the manifold heater, it is possible the heater is not working properly. You can troubleshoot the heater in the following manner:

Inspect the entire intake manifold flame heater assembly. Make sure it is all there and is connected properly. If the fuel lines, wiring, and ignition unit look all right, find out which system is at fault. It might be the fuel system or the ignition system.

First, make sure there are no leaks when the intake manifold flame heater switch is closed. Next, disconnect the high-tension lead at the spark plug. Hold the wire about 1/4 inch from the metal part of the spark plug and have someone turn on the intake manifold heater switch. If electrical sparks continue to jump the gap between the wire and the plug metal, the electrical system is all right. If no spark jumps, check out the rest of the electrical circuit.

If the electrical system is all right, check out the fuel system up to the fuel pump. Make sure the lines are not clogged. If the trouble lies in the fuel pump or nozzle, notify your support maintenance unit.

Lesson 2/Learning Event 3

You should now be able to see what makes a good troubleshooting procedure. Make sure you make an inspection before you remove any parts. Question the vehicle operator, if possible, to learn all the symptoms he may be able to give you. You may have to make an operational check to find the trouble, such as starting the engine to find a fuel leak.

Always make a functional check after you have corrected the trouble to make sure that the vehicle is in operating condition.

Lesson 2

PRACTICE EXERCISE

1. One of the functions of an injection system is to
 - a. vaporize the fuel.
 - b. meter the fuel.
 - c. clean the fuel.

2. All diesel engines require a
 - a. governor.
 - b. pressure-time pump.
 - c. compressor.

3. Compression ignition engines use a supercharger to
 - a. cool the exhaust system.
 - b. increase engine efficiency.
 - c. pressurize the fuel.

4. Fuel injection systems are used on
 - a. diesel engines only.
 - b. gasoline engines only.
 - c. diesel and gasoline engines.

5. Which item is found on all compression ignition engines?
 - a. Fuel injectors
 - b. Supercharger
 - c. Distributor

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Lesson 2

ANSWERS TO PRACTICE EXERCISE

1. b (page 31)
2. a (page 42)
3. b (page 43)
4. c (page 31)
5. a (page 31)

LESSON 3
ENGINE EXHAUST SYSTEMS

TASK

Describe the fundamentals of engine exhaust systems.

CONDITIONS

Given information about the location, purpose, construction, and inspection of engine exhaust systems.

STANDARDS

Answer 70 percent of the multiple-choice test items covering engine exhaust systems.

REFERENCES

TM 9-8000

Learning Event:

DESCRIBE THE COMPONENTS, CONSTRUCTION, AND INSPECTION OF EXHAUST SYSTEMS

INTRODUCTION

The internal combustion engine can be thought of as a mechanical device that breathes like a person or an animal. On its intake stroke, an engine cylinder inhales, pulling in fresh fuel-air mixture. On its exhaust stroke, the cylinder exhales, pushing the waste gases out.

Any defect that limits the inhaling or exhaling process seriously limits the power output. This lesson will cover the exhaust system, which is the engine's exhaling system.

The exhaust system is a relatively simple part of a vehicle. However, it is a very important part of vehicle maintenance. Above all, leaks in the system must be promptly repaired.

Lesson 3

WARNING

EXHAUST GASES CONTAIN POISONOUS CARBON MONOXIDE

As you know, exhaust gases contain carbon monoxide, which is a deadly, poisonous gas. Carbon monoxide is especially dangerous because it is colorless and odorless. The driver and passengers of a vehicle can inhale a fatal dose of carbon monoxide without knowing it. Death can result from an improperly repaired or defective exhaust system.

Also, the exhaust gas leaving the engine is very hot and contains corrosive substances. It can ruin flexible hoses, insulation on wiring, and the paint on the vehicle—as well as start fires. In addition, the exhaust gas leaves the engine under high pressure and creates a loud, undesirable noise.

The exhaust system must therefore direct the exhaust away from the operator's and passenger's compartments and away from electrical wiring and other materials that the exhaust can damage. The system must include a means of muffling the noise of the escaping gases.

EXHAUST SYSTEMS

A typical exhaust system consists of the exhaust manifold, exhaust pipe, muffler, tailpipe, and clamps. Often, the exhaust and tailpipe are made up of several pieces, and the tailpipe may have several sections.

EXHAUST MANIFOLD

The exhaust manifold collects the burned gases expelled from the engine cylinders and directs them into the exhaust pipe.

Manifolds may be made of cast iron or be assembled from steel tubing. Usually, flanges are made on the manifold where it connects to the engine and to the exhaust pipe. The mating surfaces of the flanges are machined to a smooth finish for an airtight seal against the engine and the exhaust pipe to prevent exhaust gases from leaking. Sometimes metal-to-metal contact provides the seal, but most of the time asbestos gaskets are used. Nuts made of brass are used to secure the manifold flanges because brass does not rust. The extreme heat causes steel nuts to rust very rapidly and then they are hard to remove.

Some military wheeled vehicles use exhaust manifolds with water jackets. The liquid coolant used to cool the engine passes through the exhaust manifold water jackets before returning to the radiator. This aids in reducing the temperature of the exhaust gases, reducing the amount of noise, and reducing the damage that exhaust heat causes to the exhaust system and other nearby parts.

Exhaust passages inside the manifold must be fairly smooth and free of any obstructions that would slow the flow of exhaust gases.

EXHAUST PIPE

The exhaust pipe is the passageway for the exhaust gases to flow from the manifold to the muffler. It is a heavy steel tube, usually flanged at both ends, and attached to the muffler.

The diameter of the exhaust pipe is usually determined by the size of the engine. On a small, one-cylinder engine, a pipe no larger than a household water pipe is enough to do the job. Larger engines may require exhaust pipes 3 inches or more in diameter to carry the larger amount of exhaust gases.

The length of the exhaust pipe is determined by the design of the vehicle. If the engine is in the front of the vehicle and the muffler is mounted in the rear, the pipe will be long. (Often, long pipes will be made in two sections.)

To provide as much road clearance as possible, pipes are formed in odd shapes that fit well up under the vehicles without touching other components. Pipes are supported from the vehicle frame by hangers. (The center portion of the hanger can be made of flexible material to absorb vibration.)

MUFFLER

The purpose of the muffler is to muffle the exhaust noise. A “perfect” muffler would silence all the noise made by the exhaust gases and would eliminate all back pressure. However, it is not practical to make a muffler so perfect. All mufflers in common use do cause some back pressure and do not silence all the noise.

There are two basic muffler designs: straight-through and baffle.

The straight-through type has a pipe extending straight through the muffler and a chamber surrounding it. Holes are drilled all around the pipe, and metal shavings or glass wool is packed in the chamber that surrounds the through pipe.

Lesson 3

On the baffle-type muffler, the exhaust must travel through holes in several baffles before it escapes through the muffler outlet. Often, a small hole is drilled in the bottom of the muffler to allow condensed water to drain.

Mufflers are made of sheet metal and are crimped or welded together at the seams. They cannot be disassembled.

The muffler reduces most of the noise by cooling the hot exhaust gases to reduce the pressure. The chambers between the baffles inside the baffle-type muffler also produce a deadening effect by smoothing out the surges of gases flowing from the cylinders.

The straight-through muffler will cause very little back pressure but does not do as good a job of muffling the noise. The baffle muffler causes more back pressure but does a better job of muffling the noise.

TAILPIPE

The tailpipe carries exhaust gases from the muffler outlet to a point where they can be safely ejected.

It is made of steel tubing and may be a little smaller in diameter than the exhaust pipe. A smaller pipe can be used because the muffler has cooled the gases a great deal, causing them to contract. The pipe may be secured to the muffler by either a flange or a slip-together connection. To ensure that the pipe stays in the proper position along the body or frame of the vehicle, hangers are used. Some trucks have their tailpipes run up beside the vehicle cab.

For deep-water fording, a special tailpipe extension is usually required. The extension is connected to the tailpipe and extends up alongside the vehicle body. Pipes like these should either be curved outward at the end or have a weather cap installed. Otherwise, rain water can enter the pipe. The weather cap may be a flapper valve closed by a spring or kept closed by the weight of the valve and opened by exhaust pressure.

SINGLE OR DUAL EXHAUST SYSTEMS

Vehicles with V-type engines may have single or dual exhaust systems. When the dual system is used, each bank of cylinders has a separate exhaust system with its own manifold exhaust pipe, muffler, and tailpipe.

The dual exhaust permits the exhaust gases to travel in a straighter path to the rear of the vehicle. Therefore, the dual exhaust system causes less back pressure than the single and is desired for best engine performance. However, the additional parts make dual exhaust systems more expensive than single exhaust systems.

If a single exhaust system is used on a V-type engine, the exhaust gases from the two banks of cylinders must be brought together at some point. On some engines, a crossover pipe made from a steel tube connects the two exhaust manifolds. Exhaust gases from both cylinder banks then leave through one exhaust pipe that is connected to one of the exhaust manifolds. Another method is to bring together the exhaust pipes from the right and left cylinder banks, forming a "Y" connection.

TURBOCHARGER

A turbocharger, when used, is mounted in the exhaust system. Its turbine housing is generally connected directly to the outlet of the exhaust manifold. All exhaust gases leaving the manifold pass through the turbine housing, to drive the turbocharger, and then escape through an exhaust elbow to the exhaust pipe. Driving the turbocharger slows down the exhaust gases somewhat. As you know, slowing down the exhaust gases reduces the engine's power output. With the turbocharger, however, the power loss due to slowing the exhaust gases is more than made up by the increased intake air pressure.

SPECIAL BYPASSES

Water tankers of 2 1/2-ton trucks have a special bypass in their exhaust systems. The bypass is used in cold weather to direct the hot gases into a chamber under the water tanks to help keep the water from freezing. A bypass control valve is mounted in the exhaust system at the rear of the exhaust pipe and in front of the muffler. The control valve can direct the exhaust gases either to the muffler or to the chamber under the water tank. A control lever to operate the bypass control valve is located in the vehicle cab.

Lesson 3

INSPECTION

Inspection procedures for exhaust systems are about the same regardless of which type of vehicle you are working on.

To inspect the exhaust system, you will depend mostly on your senses of sight, hearing, and feel. Start at either end of the exhaust system and work toward the opposite end, inspecting for leaks and for loose, missing, defective, and improperly positioned components.

Above all, don't operate the vehicle engine for more than a minute or two unless it is located in a well-ventilated area. Otherwise, you may become a victim of carbon monoxide poisoning. Also, watch out that you don't burn yourself on any of the hot exhaust system parts.

Exhaust gas leaks are the most serious problems. You must make sure that you find and make a note of all of them, regardless of how small they are. Bad leaks make a lot of noise, so you can easily locate the general area they are coming from. Small leaks can be heard if you momentarily plug the tailpipe outlet. This causes any leaks to make a hissing noise due to back pressure building up in the exhaust system. After you find the general area of the leak, hold your hand near the suspected leak. You can feel escaping gases striking your hand. Be careful that you don't get your hand too close and get burned.

Inspect the exhaust manifold for tightness and cracks. Look closely for black carbon deposits that indicate a leak. All heat deflectors and shields must be secure and properly positioned to protect nearby parts from the heat.

When inspecting the exhaust pipe, muffler, and tailpipe, pay particular attention to damage caused by rust and corrosion, as this is the main cause of these parts going bad. Often, a muffler may look good from the outside but may be rusted away on the inside. Bump the muffler several times with your hand. If it rattles on the inside, the baffles are rusted loose and the muffler needs to be replaced.

All parts must be held securely in proper position by the hangers and not allowed to bump or rattle against the vehicle body, frame, or power train parts. There must be ample space between all hot exhaust system parts and items such as electrical wiring, brake hoses, and fuel lines. Even without touching, the insulation on wiring can burn away, and fuel can boil in a line.

Lesson 3

Any large dents in the muffler, exhaust pipe, or tailpipe will slow down the flow of escaping gases and reduce engine power. A muffler that is full of carbon deposits will also restrict gas flow. You cannot see this kind of restriction, but if you suspect it, connect a vacuum pressure gage to the intake manifold. If the exhaust system is restricted, the manifold vacuum will read normal when the engine is first started but will drop rapidly.

Repair of the exhaust system is almost always limited to the replacement of parts. Never attempt to remove parts while they are still hot.

Lesson 3

PRACTICE EXERCISE

1. Immediate repair of exhaust systems is important to prevent
 - a. engine overheating.
 - b. exhaust back pressure.
 - c. injury to personnel.

2. A small hole is drilled in the bottom of some mufflers to allow
 - a. excess pressure to escape.
 - b. condensed water to drain.
 - c. cooling air to enter.

3. A turbocharger is usually connected to the
 - a. exhaust manifold.
 - b. muffler.
 - c. connecting pipe.

4. A muffler that is rusted away on the inside can best be detected by
 - a. testing for restrictions.
 - b. listening for rattles.
 - c. examining the muffler.

5. A dual exhaust system decreases
 - a. cost of the system.
 - b. exhaust back pressure.
 - c. manifold temperature.

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Lesson 3

ANSWERS TO PRACTICE EXERCISE

1. c (page 59)
2. b (page 62)
3. a (page 63)
4. b (page 64)
5. b (page 63)